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Description

FIELD OF INVENTION

This invention relates to the cleaning and removal of solids from microporous hollow fibre filters.

BACKGROUND ART

WO-A-85/01449 (EP-A-0160014) and WO-A-86/05116 (published 12.09.86, filed 03.03.86, earliest priority claimed 05.03.85; corresponds to EP-A-0213157) describe methods for backwashing elastic microporous hollow fibre filters. The filters disclosed in these applications consist of a bundle of polymeric (such as polypropylene) fibres contained within a housing having a feedstock inlet thereto and a concentrate outlet therefrom. The feedstock is applied to the outside of the fibres and some of the liquid contained in the feedstock passes through the walls of the fibres and is drawn off from the fibre lumens as filtrate.

The fibres are cast in resin at both ends of the shell or housing with the ends of the lumens open to constitute a tube-in-shell configuration. Although not described in our above mentioned specifications, the fibres may be cast into one end of the housing with the other ends of fibres free but with the free ends of the lumens sealed to constitute a candle-in-shell configuration.

During the filtering operation, which may be either to recover clarified liquid or to recover concentrated solids, solids contained in the feedstock either pass out of the shell with the remainder of the feedstock carrier stream, or are retained on or in the fibres. These retained solids cause fouling and blockage of the filter.

Industrial practice with the more common tube-in-shell microfilters for many years was commonly to apply the feedstock to the inner surface of the fibres by forcing flow through the fibre lumens at such a rate that turbulence scoured the walls of the fibres, retarding blockage by solid material.

In the above mentioned specifications, the feedstock is applied to the outer surface of the fibres, with a penalty of low feedstock flow velocity and consequent low turbulence resulting in a rapid rate of blockage of the pores of the fibres. This is overcome by the application of a two-stage backwashing cycle.

In the first stage a liquid backwash is applied to the lumens of the fibres such that the liquid passes through the porous walls of the fibres and sweeps retained solids out of substantially all of the pores in the walls of the fibres. In the second stage, a gaseous backwash is applied to the lumens of the fibres such that the gas passes through the larger pores in the walls of the fibres, stretching them and dislodging retained blocking solids.

The above mentioned WO-A-86/05116 discloses a method of applying pressure such that the gaseous backwash is applied evenly over the inner surface of the hollow fibres. In this method, the volume of liquid backwash is that volume of liquid trapped in the pores of the walls of the fibres. When the backwash stage is begun, low pressure gas is applied to clear the fibre lumens of liquid, and then high pressure gas is applied so as to exceed the bubble point of the fibres and force gas through the larger pores in the fibre walls.

The application of the two-stage backwashing regime discussed above restores filtrate flux to a high value that is however, not as high as the initial value. At each stage this slight diminution of flux reduces the filtration capacity of the fibres. Eventually chemical cleaning is required. This is expensive and time consuming.

Another method of cleaning the fibres is known as reverse flow and is reviewed in "Ultrafiltration Membranes and Application", Edited by A.R. Cooper, a record of a Symposium of the American Chemical Society, September 11-13, 1979, Pages 109 to 127, "Advances in Hollow Fibre Ultrafiltration Technology", by B.R. Breslau.

In the Breslau method the feed is applied to the lumens of the fibres at high velocity so that there is a large pressure drop down the length of the fibres. By closing off the filtrate flow at the distal end of the shell, the filtrate pressure climbs within the shell and forces filtrate backwards through the fibre walls in the distal end of the fibre bundle. The direction of flow of feedstock is then reversed and the process repeated so as to force filtrate backwards through the fibre walls in the proximal end of the fibre bundle. Filtrate is produced in one end of the shell and used to backwash the fibres at the other end of the shell. This technique can also be carried out using a chemical cleaning solution. Use of gas for backwashing is not mentioned.

A distinction is made between the term "reversed flow (filtering)" as used by Breslau and the description of reversing the direction of flow while no filtering is occuring as hereinafter described.

The prior art also contains a number of references to filter systems which utilise pressure variations arising, inter alia, from induced gas pressure.

For example, DE-A-2,833,994 discloses a filtration process in which two fluid streams flow countercurrent to each other on either side of a filter medium. The flow of filtrate is subjected to a series of reductions of the flow cross section. These reductions with the associated acceleration in velocity induce a region of low pressure below the membrane, causing a flow of fluid through the membrane.

NL-A-7,604,657 discloses a method for cleaning tubular membranes in which gas is dissolved in a liquid under pressure. The liquid is fed past the membrane and the pressure is reduced so that gas is released as small bubbles which lift solids from the membrane and carry them away.

Similarly, the feeding of gas - liquid mixture to the surface of the membrane is taught by JP-A-61-129094 (feed side) and JP-A-56-024006 (backwash).

The cleaning of dead-end fibres dangling in a pot by gaseous backwash cleaning causing writhing of the fibres is disclosed in GB-A-2,120,952. JP-A 60-137404 teaches the installation of special equipment to vibrate dead-end fibres hanging in a pot during gaseous backwash and SU-A-715,105 discloses air pulsing of wash water applied to a granulated filter.

JP-A-53-042186 teaches the periodic reversal of direction of flow of feed liquid in a membrane plate separator. JP-A-61-101209 discloses a method of applying a vacuum to eliminate air from the pores of a hydrophobic membrane.

JP-A-47-021748 discloses the reversal of application of air pressure. First air pressure drives liquid through the membrane. When backwashing with filtrate is required, the air pressure is applied to the filtrate. When a flow meter indicates sufficient washing, the air pressure is again applied to the feed side to restart the filtration.

The article "Anti-fouling Techniques in Cross-flow Microfiltration" by Milisic & Bersillon, Filtration & Separation, November/December 1986, pp 347-349, teaches pulsing the feedstream as it is applied during normal filtration.

Banks of fibres in shell filter cartridges are frequently arranged in parallel. When one shell develops a blockage, flow bypasses this fibre bundle, the velocity slows, and the blockage becomes self-increasing through the system.

The need to optimise the frequency of cleaning cycles to maximise filtrate flow is discussed in WO-A-85/01449.

For the procedure described to be successful, the fibres must be elastic. For practical considerations of each of manufacture and resistance to acid cleaning that must be applied eventually, and for strength, the fibres are generally chosen to be a thermoplastic such a polypropylene. Such thermoplastics are fundamentally hydrophobic and must be wetted before they can be used to filter aqueous feedstock streams.

The application of backwashing gas as described above has the undesired effect of partially drying the fibres. Small bubbles of gas are retained in the pores in the walls of the fibres where they effectively block filtration. The filtrate flux is initally high at the start of filtration, but rapidly drops as the fibres foul with solids. The application of the two stage backwashing regime restores the filtrate flux to a high value that is however, not as high as the initial value. At each stage this slight diminution of flux reduces the filtration capacity of the fibres. Eventually chemical cleaning and/or rewetting is required which is expensive and time consuming.

WO-A-84/03229 discloses the pressurized initial wetting of fibres in relation to cartridge units that are intended for a special use such as with blood, and which can be prewetted before shipment. However, in industrial situations, cartridges may be used for many applications that are not specified at the time of manufacture of the cartridge. For applications such as food use, the presence of extraneous wetting agents such as surfactants must be avoided and there is a need to wet the fibres with the liquid to be filtered. In these cases it is impractical to wet the fibres during manufacture. They must be wetted in place, immediately prior to use.

JP-A-60-197206 discloses cleaning of a permeable hollow yarn membrane of an ultrafiltration unit by filling the permeated water chamber with a sterilised gas, closing the chamber, and pressurising the original water for a predetermined time. By decreasing the pressure, by exhausting water from an original water outlet, accumulated material is peeled off to the original water side.

In GB-A-1535832 there is described cleaning of accumulated fouling matter from the feed side of a semi-permeable membrane of a pressure driven membrane processing apparatus by injecting a stream of gas into the feed side of the apparatus in the opposite direction to feed flow to expel residual feed liquid from the apparatus.

The procedure described in our International Patent Application WO-A-86/05116 (European Patent Application EP-A-0213157) utilises a flow of feedstock to wash away the dislodged solids. However, it is

sometimes necessary that the solid material be recovered in a drier state than is the case with the processes described in our above International Patent Applications. This is particularly useful where solids recovery and dewatering are important.

According to the present invention there is provided a method of operating a filter having elastic, porous hollow fibres within a tubular shell or housing having a first port adjacent one end of the tubular shell or housing and a second port adjacent the other end of the tubular shell or housing, one of said ports serving as a feed inlet to the shell or housing and the other of said ports serving as a feed outlet from the shell or housing, said shell or housing optionally having a third port intermediate the feed inlet and the feed outlet, the method comprising the steps of:

(i) introducing a liquid suspension feedstock through the feed inlet to the shell or housing and directing said feedstock to the outer surface of the fibres whereby:

(a) some of said feedstock passes through the walls of the fibres to be drawn off from the fibre lumens as a filtrate or permeate; and

(b) some of the solids in said feedstock are retained on or in the pores of the fibres, with the non-retained solids being discharged through the feed outlet from the shell or housing with the remainder of said feedstock, and

(ii) periodically cleaning away the retained solids by steps including

A) introducing a pressurised gas into the fibre lumens while liquid is flowing through the shell or housings, said pressurised gas being at a pressure sufficient to cause the gas to pass through the walls of the fibres against the pressure ("the normal gaseous cleaning pressure") then prevailing on the shell side with liquid flowing,

B) then, while maintaining pressurised gas flow into the fibre lumens, either increasing the shell side pressure above the normal gaseous cleaning pressure by stopping outflow of liquid from the shell or housing or decreasing the shell side pressure below the normal gaseous cleaning pressure by stopping inflow of liquid to the shell or housing and thereafter

C) returning to the normal gaseous cleaning pressure by resuming flow of liquid through the shell or housing in a reverse direction.

Preferably the fibres are microporous fibres and, prior to the introduction of the pressurised gas, a pressurised liquid is introduced through the fibre lumens and passes through the walls of the fibres to wash out at least some of the retained solids and the pressurised gas is applied at a pressure which is sufficient to stretch elastically at least some of the pores in the walls of the fibres to dislodge any solids retained in those pores and to wash the external walls of the fibres and which is sufficient to overcome the resistance to gas flow of the surface tension of the continuous phase of the filtrate within the pores of the fibres.

The pressure within the shell is varied during cleaning by increasing the pressure within the shell above the normal gaseous cleaning pressure and then returning the pressure to the normal gaseous cleaning pressure or by decreasing the pressure within the shell below the normal gaseous cleaning pressure and then returning the pressure to the normal gaseous cleaning pressure.

The pressure within the shell is increased by terminating the outflow of feed and then returned to the normal gaseous cleaning pressure by recommencing flow of feed in the reverse direction.

The pressure within the shell is decreased by terminating the inflow of feed and the return to normal gaseous cleaning pressure can be achieved by resuming inflow of feed in the reverse direction.

All the above variations in the mode of operating the filter during the cleaning cycle may be repeated a number of times during gaseous cleaning.

In one form of the invention, the shell is pressurised by terminating feed flow before the pressure variation step and the pressure is released by recommencing feed outflow prior to the application of the pressure variation step.

In a modification of this form of the invention, the pressure is released at both the feed and recirculation ends of the shell.

The methods of the invention may also be modified by including a step of pressurising the fibres after the completion of the backwash and then releasing that pressure to remove trapped air from the pores of the fibres. The step of pressurising the fibres may be carried out by terminating the feed inflow and feed outflow and the pressure may be released by recommencing feed inflow with or without recommencement of feed outflow. The pressurisation of the fibres is carried out whilst lumen flow is blocked preferably in a pulsing fashion.

To carry out the pressurisation, after the backwash cycle has been completed, the feedstock and filtrate flow are blocked. A hydraulic pressure preferably driven by pressurised gas is applied to either the filtrate side of the fibres or the feedstock side of the fibres, or both. Thus pressure is applied to the fibres and the compressible gas contained in the pores of the fibres is reduced in volume or dissolved in the liquid in the

fibres due to its greater solubility under pressure. On resumption of feed flow the gas is expelled.

In some circumstances it may be preferable to drain the fibre lumens before commencing of the gaseous backwash step. Furthermore, it may be advantageous to drain the shell before commencement of backwash.

According to another aspect of the invention, the introduction of the pressurised gas for cleaning includes the preliminary steps of:

(a) initially applying the gas at a pressure below the bubble point of the walls of the fibres so as to displace any liquid from the fibre lumens,

(b) terminating feed inflow and outflow by closing the feed inlet to and the feed outlet from the shell or housing,

(c) increasing the pressure of the gas above the bubble point of the walls of the fibres, and

(d) recommencing feed inflow and outflow by opening the feed inlet and feed outlet to allow the gas to escape substantially uniformly through the fibre walls.

The filter may be operated in a cross flow mode or in a dead-end filtering mode with no outflow of feed and solids from the shell during the dead-end filtration mode.

In yet another embodiment of the invention, the backwashing cleaning step is enhanced by discharging through both the shell inlet and outlet and feeding through an additional line connected to the shell between the shell inlet and outlet.

The invention also includes a filter system comprising:

(a) a tubular shell or housing,

(b) a plurality of elastic, porous hollow fibres within the shell or housing,

(c) a first port adjacent to one end of the shell or housing,

(d) a second port adjacent to the other end of the shell or housing,

(e) a filtrate outlet from the shell or housing communicating with the lumens of the fibres,

(f) shell inlet valve means for introducing a liquid suspension feedstock through one of said first and second ports as a feed inlet to the shell or housing and for directing said feedstock to the outer surface of the fibres whereby:

(i) some of said feedstock passes through the walls of the fibres to be drawn from the fibre lumens as a filtrate or permeate and to be discharged through the filtrate outlet, and

(ii) some of the solids in said feedstock are retained on or in the pores of the fibres, with the non-retained solids being discharged through the other of said first and second ports as a feed outlet from the shell or housing with the remainder of said feedstock,

(g) shell outlet valve means for controlling the outflow through the shell outlet,

(h) gas control valve means for introducing a pressurised gas into the fibre lumens with liquid flow through the shell side of the fibre walls at a pressure sufficient to cause the gas to pass through the walls of the fibres against the pressure ("the normal gaseous cleaning pressure") then prevailing with liquid flow through the shell side thereby to cause gas to pass through the walls of the fibres to dislodge retained solids,

(i) valve means for reversing the flow of feedstock through the shell, and

(j) control means for varying the pressure within the shell or housing, whilst the gas is being introduced into the lumens, said control means being adapted either

- to actuate the shell outlet valve means to increase the pressure within the shell or housing on the shell side of the fibre walls above the normal gaseous cleaning pressure by stopping outflow of liquid from the shell or housing through the shell outlet;

  or

- to actuate the shell inlet valve means to decrease the pressure within the shell or housing on the shell side of the fibre walls below the normal gaseous cleaning pressure by stopping inflow of liquid to the shell or housing through the shell inlet; said control means further being adapted to actuate said flow reverse valve means to then return the pressure within the shell or housing on the shell side of the fibre walls to the normal cleaning pressure by resuming flow of liquid through the shell or housing in a reverse direction whereby said one port now becomes the feed outlet and said other port now becomes the feed inlet.

In order that the invention may be more readily understood and put into practical effect, reference will now be made to the accompanying drawings in which:

Fig. 1 is a schematic view of a hollow fibre cross-flow filter shown in its operating mode,

Fig. 2 is a schematic view similar to Fig. 1 with the filter shown in its gas backwash cleaning mode,

Fig. 3 is a graph of clarified liquid flux against time for a hollow fibre cross-flow concentrator,

Fig. 4 is a partly broken away view of one end of the filter cartridge shown in Figs. 1 and 2,

Fig. 5 is a view similar to Fig. 4 of a modified form of the cartridge end,
Fig. 6 is a view similar to Fig. 4 of a further modified form of the cartridge end,
Fig. 7 is a schematic diagram of a filtering installation for the application of the method of the invention,
Fig. 8 is a simplified schematic diagram of a modified form of the installation shown in Fig. 7,
Fig. 9 is a graph of filtrate flux against time for a filtration system for three modes of operation,
Fig. 10 is a graph of filtrate flux against time for a filtration system comparing two modes of operation,
Fig. 11 is a graph of flux against time for the filtration of a feedstock using mode 1(b) backwash,
Fig. 12 is a graph of flux against time similar to Fig. 11 but showing a mode 2(b) backwash, and,
Fig. 13 is a graph similar to Fig. 12 but with four cycles of reverse flow of feedstock followed by a backwash of mode 2(b).

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The hollow fibre cross-flow concentrator 10 shown in Figs. 1 and 2 includes a cartridge shell 11 within which is positioned a bundle of hollow, porous, polymeric fibres 12. In this instance, each fibre is made of polypropylene, has an average pore size of 0.2 micrometers, a wall thickness of 200 microns and a lumen diameter of 200 micrometers. There are 3,000 hollow fibres in the bundle 12 but this number as well as the individual fibre dimensions may be varied according to operational requirements.

Polyurethane potting compound 13, 14 holds the ends of the fibres 12 in place without blocking their lumens and closes off each end of the shell 11. The liquid feed suspension to be concentrated is pumped into the shell 11 through feed suspension inlet 15 and passes over the external walls of the hollow fibres 12. Some of the feed suspension passes through the walls of the fibres 12 into the lumens of the fibres to be drawn off through the lumen outlet ports 16 and 18 as clarified liquid.

The remaining feed suspension and some of the rejected species flows between the fibres 12 and leaves the shell 11 through outlet 17. The remainder of the rejected species is held onto or within the fibres or is otherwise retained within the shell.

In order to remove the retained species, lumen outlet port 16 is closed so that the flow of clarified liquid is stopped. Pressurised clarified liquid is then introduced into the lumens through lumen inlet port 18 to stretch substantially all of the pores and to wash them with at least the total pore volume of clarified liquid. Upon completion of the clarified liquid purge, compressed gas is introduced through lumen inlet port 18, along the lumens of the fibres 12 and through the walls of the fibres into the feed suspension/concentrated steam causing violent bubbling which purges the shell of any retained species which may have built up on the outer walls of the fibres or may have been washed from within the pores of the fibres by the clarified liquid purge.

In one embodiment of the invention (which is particularly suitable for long thin fibres), the compressed gas is introduced through inlet 18 and along the lumens of the fibres 12 after opening the lumen outlet port 16 for a limited period so that no gas penetrates the pores of the fibres at this stage. The liquid-filled shell is then sealed by closing shell inlet 15 and shell outlet 17. Gas still cannot penetrate the porous walls even though the gas pressure is now raised well above the normal bubble point of the fibre walls because the liquid within the shell is relatively incompressible. A reservoir of high pressure gas is thus accumulated in the fibre lumens.

The shell outlet 17 is then opened which allows gas to penetrate the pores along the whole length of each fibre. Initially, the surge of bubbling gas is substantially uniform but ultimately is slower at the end remote from lumen inlet port 18 due to the viscous pressure drop along the thin fibres. In extreme cases, it is desirable to admit gas through both lumen ports 16 and 18 after carrying out the above described pressurised, trapped gas operation.

It is preferred that the resumption of feed suspension flow after gaseous cleaning be delayed for sufficient time to enable the pores that have been stretched by the gas to recover to their original size so that over-sized particles from the feed suspension will not be able to pass into or through the enlarged pores.

Fig. 3 shows the effect of the solid discharges described in relation to Fig. 2 upon the rate of production of clarified liquid. Curve A shows the decay of clarified liquid flux against time without discharge of solids, whereas Curve C show the recovery of clarified liquid flux after each combined liquid and gaseous discharge cycle. Although the discharge of solids returns the clarified liquid flux to almost the initial value, a decrease in efficiency may occur over an extended period of time notwithstanding successive discharges. The slight reduction in the filtration capacity of the fibres at each stage eventually results in a need for chemical cleaning, which is expensive and time consuming.

One end of the filter cartridge shown in Figs. 1 and 2 is shown on an enlarged scale in Fig. 4. It will be seen that the tubular shell 11 projects into a housing 20 that carries the feed suspension outlet 17 and filtrate discharge port 16. The housing 20 is made of two parts 21, 22 within which is located a collar 23 that supports a spigot 24 leading to the outlet 17. In this embodiment of the cartridge, the inner end 25 of the spigot 24 is flush with the inner surface of the collar 23 and the shell 11 projects into housing part 21 with its end 26 terminating beyond the spigot 24.

The modified version of the end of the cartridge shown in Fig. 5 is substantially similar to that shown in Fig. 4, the differences being that the inner end 26 of the shell 11 does not project into the housing part 21 and that the inner end 25 of the spigot 24 projects beyond the inner surface of the collar 23 and that the inner end 25 of the spigot has a cut-away portion 27.

The modified version of the end of the cartridge shown in Fig. 6 is substantially similar to that shown in Fig. 5, the difference being that the inner end 26 of the shell 11 does project into housing port 21 but terminates short of the spigot 24.

The techniques of the invention can be implemented using the installation shown in Fig. 7. In Fig. 7, feed line 50 from the tank 51 to feed pump 52 and check valve 53 branches into lines 54 and 55. Manual valve 56 in line 54 is closed during normal filtration. Feed in line 55 passes through feed valve 63 and into the shell side of filter 57 through feed line 64. Feed discharged from the filter 57 flows through line 58 into line 59 having a pressure gauge 60 and then into the main return line 61 which has a manual control valve 62.

Filtrate from the filter 57 is discharged through filtrate lines 65 and 66. Filtrate from line 65 passes through line 67 which has a manual control valve 68 and line 84 which has a pressure gauge 69 to filtrate discharge line 70 which also has a manual control valve 71. Filtrate from line 66 is also discharged through line 70.

Gas may be introduced into line 84 from line 72 which contains a check valve 73. A discharge line 74 is connected to the feed line 64 and contains a manual drain valve 75 and pressure gauge 76. The discharge line 74 is connected to the main discharge line 77 as is line 78 which has a manual drain valve 79. A return line 80 connected between the filtrate lines 65 and 67 and tank 51 has a manual valve 81. An additional gas line 82 controlled by valve 83 enters feed line 50 downstream of the check valve 53.

During normal filtration pump 52 is on and valves 63, 71, 68 and 62 are all open and valves 56, 79, 75 and 81 are closed. Desired operating pressures are set by adjusting manual valves 63 and 62.

The filter installation shown in Fig. 7 can operate in number of different modes of backwashing by manipulating the various valves, altering the flow pattern and by changing the identity (liquid or gas) of the medium in one, some or all of the lines.

In brief terms, these modes of backwash may be identified as:-

MODE 1	NORMAL BACKWASH (Comparative Mode)
MODE 2	PRESSURE INCREASE WITH REVERSE FLOW OF FEED DURING BACKWASH
MODE 3	PRESSURE DECREASE WITH PULSING FEED INFLOW (Comparative Mode)
MODE 4	PRESSURE INCREASE WITH PULSING FEED OUTFLOW (Comparative Mode)
MODE 5	PRESSURE DECREASE WITH REVERSE FLOW OF FEED
MODE 6	RELEASING SHELL PRESSURE AT BOTH INLET AND OUTLET POINTS DURING BACKWASH
MODE 7	REWETTING PRESSURISATION

Comparative modes do not fall under the scope of claim 1.

All the first six modes may be effected by either first draining the lumens or not draining the lumens. Thus, the above modes will be identified as (a) when the lumens are drained and (b) where the lumens are not drained where such distinction is appropriate.

It is convenient to describe Mode 2 before Mode 1 as the latter consists of seven stages which are common to the ten stages of Mode 2.

MODE 2 - PRESSURE INCREASE WITH REVERSE FLOW OF FEED

The reverse flow of feed during backwash mode consists of ten stages. During stage 1, pump 52 is off, valves 63, 56, 79, 75, 71, 68 and 62 are closed and valve 81 is open. Low pressure gas is introduced via line 72 and check valve 73. The gas flows through lines 84 and 66 and into the bottom filtrate port of cartridge bank 57. Filtrate from within the lumens is flushed out and exits via lines 65 and 80 back to tank 51. During this stage, the gas pressure is held low, below the bubble point, so that there is no gas breakthrough across the membrane.

During stage 2, pump 52 remains off, valve 73 remains open and valves 63, 56, 79, 75, 71 and 62 remain closed. Valve 81 is closed and valve 68 is opened. High pressure gas is then introduced via lines 72, 67, 84, 66 and 65. This pressurises both the lumen side and the shell side of the cartridge bank 57, typically to 600KPa(g).

During stage 3, pump 52 remains off, valves 63, 56, 75, 71, 81 and 62 remain closed and valves 68 and 73 remain open. Valve 79 is opened to release the shell side pressure with high pressure gas still being applied to the lumens via lines 72, 67, 84, 66 and 65. The gas passes through the pores of the fibres to the shell side of the filter 57 and exits via lines 58, 59, 78 and 77. The purpose of this third stage is to dislodge accumulated solids from the outside of the fibres.

During stage 4, the valve settings are the same as for Stage 3 except for valve 63 which is now opened. Pump 52 is turned on and remains on until the next backwash sequence is started. High pressure gas is still applied to the lumens via lines 72, 67, 84, 66 and 65. The purpose of this fourth stage is to wash dislodged solids to drain, via lines 58, 59, 78 and 77.

During stage 5, valves 68 and 73 remain open and valves 56, 71, 75, 81 and 62 remain closed. Valves 63 and 79 are closed and high pressure gas is still applied to the lumens via lines 72, 67, 84, 65 and 66 which pressurises both the lumens and the shell side of the cartridge bank 57.

During stage 6, valve settings are the same as for Stage 5 except for valves 56 and 75 which are opened to release the shell-side pressure with high pressure gas still applied to the lumens. The flow of feed down the cartridge bank 57 is now reversed, and the dislodged solids are carried away via lines 64, 74 and 77.

The seventh stage is the same as the fifth stage and the eighth stage is the same as the fourth stage. The total sequence of stages 4, 5, 6, 5, 4 is repeated one or more times.

Stage 9 is the same as stage 4 except the high pressure gas is turned off to remove residual gas in the feed stream to drain via lines 58, 59, 78 and 77.

For stage 10, valves 63, 68 and 81 are open, valves 56, 79, 75, 71 and 62 are closed and the high pressure gas remains off to remove residual gas in filtrate lines 65, 66, 67, 84 and 80. At the completion of stage 10, the installation is returned to normal filtration.

<u>MODE 1 - NORMAL BACKWASH</u> (Comparative Mode)

The normal backwash mode consists of stages 1 to 4 and 9 to 10 of Mode 2. Thus, during stage 1, low pressure gas is introduced into the lumens to drain filtrate from the lumens. During stage 2, the gas pressure is increased to pressurise both the lumen side and the shell side of the filter 57.

At stage 3, drain valve 79 is opened to release the shell side pressure whilst high pressure gas is still being applied to the lumens to dislodge accumulated solids from the outside of the fibres. Feed valve 63 is opened and the pump 52 turned on in stage 4 to wash the dislodged solids through drain valve 79 to discharge line 77.

The high pressure gas is then turned off (stage 9) and residual gas in the feed stream is discharged through lines 59 and 78 to discharge line 77. In the final stage (stage 10), residual gas in the filtrate lines 65, 66 and 67 is discharged through line 80 to the tank 51. At the completion of stage 10, the installation is returned to normal filtration.

<u>MODE 3 - PRESSURE DECREASE WITH PULSING FEED INFLOW</u> (Comparative Mode)

In this mode, stages 1 to 4 are the same as those described above in relation to mode 2. Thus, low pressure gas is used to drain the lumens (stage 1), high pressure gas is used to pressurise both the lumen side and the shell side of the filter (stage 2), drain valve 79 is opened to release the shell side pressure to dislodge accumulated solids (stage 3) and feed flow recommenced through feed valve 63 to wash the solids through the drain valve 79 to discharge line 77 (stage 4.).

Stage 5 is the same as stage 4 except that the feed valve 63 is closed to drop the shell side pressure of the cartridge 57 below the normal gaseous cleaning pressure.

Stage 6 of this mode is the same as stage 4, that is, valve 63 is opened so that the pressure on the shell side returns to the normal gaseous cleaning pressure. Stage 7 of this mode is the same as stage 5 and stage 8 of this mode is the same as stage 4.

The total sequence of stages 4, 5, 4 in order (i.e. stages 4 to 8) is repeated one or more times. Stages 9 and 10 of this mode are the same as stage 9 and 10 of Mode 2.

MODE 4 - PRESSURE INCREASE WITH PULSING FEED OUTFLOW (Comparative Mode)

In this mode, stages 1 to 4 are the same as Stages 1 to 4 of Mode 2.

Stage 5 of this mode is the same as stage 4 of this mode except that drain valve 79 is closed so that the pressure on the shell side of the filter cartridge 57 is increased from the normal operating gaseous cleaning to the pressure on the lumen side.

Stage 6 of this mode is the same as stage 4 of this mode. Thus, valve 79 is opened and feed flow recommenced. The pressure on the shell side of the cartridge drops back to the normal gaseous cleaning pressure.

Stage 7 of this mode is the same as stage 5 of this mode and stage 8 of this mode is the same as stage 4 of this mode.

The total sequence of stages 4, 5, 4 in order of (i.e. stages 4 to 8) is repeated one or more times with the action to initiate the pressure variation cycle always being applied at the same end of the shell. Stages 9 and 10 are the same as stages 9 and 10 of Mode 2.

MODE 5 - PRESSURE DECREASE WITH REVERSE FLOW OF FEED

This mode follows stages 1 to 5 of Mode 3. In stage 6, valves 56, 75 and 68 are open and valves 63, 79, 73, 81 and 62 are closed. Pump 52 is on and high pressure gas is still applied through line 72. Dislodged solids are removed through lines 64, 74 and 77.

Stage 7 of this mode is the same as stage 5 of Mode 3 and stage 8 of this mode is the same as stage 4 of Mode 3.

The total sequence of stages 4, 5, 6, 5, 4 in order (i.e. stages 4 to 8) is repeated one or more times.

It should be noted that the pressure cycle introduced after stage 4 of modes 2 to 5 can be either pressure increases from normal gaseous cleaning pressure and then returns to the normal gaseous cleaning pressure (modes 2 and 4), or, pressure decreases from normal gaseous cleaning pressure and then returns to normal gaseous cleaning pressure (modes 3 and 5).

With modes 2 and 4, after the pressure increase, the pressure release is always at the feed outflow end of the shell. With mode 4, the feed outflow is always at the same end of the shell with mode 2, the feed outflow alternates from one end of the shell to the other on each cycle.

With Modes 3 and 5, after the pressure decreases, the pressure is always at the feed outflow end of the shell. With modes 4 and 3 the feed inflow is always at the same end of the shell. With modes 2 and 5 the feed outflow alternates from one end of the shell to the other on each cycle.

MODE 6 - RELEASING SHELL PRESSURE AT BOTH INLET AND OUTLET POINTS DURING BACKWASH

This mode can be applied to Modes 1 to 5. The pressure release refers to the release of the pressure built up within the shell during stage 2 of Modes 1 to 5 which is different from the pressure variation cycle introduced after stage 4. To achieve the release of pressure at both the inlet and outlet points of the shell, stage 3 is modified by additonally opening valve 75 to equalise the trans membrane pressure down the filter cartridge bank 57.

MODE 7- REWETTING PRESSURISATION

A rewetting of the membranes stage can follow any of the above modes. The rewetting stage may be applied when a backwash cycle is complete, or at any other time. The rewetting cycle consists of subjecting the fibres to a pressurisation followed by a fast release of pressure to remove trapped air which is blocking the fibres. This can be achieved in the following three steps:-

In step 1, valves 79, 75, 71, 81 and 62 are closed, valves 63, 56 and 68 are open and high pressure gas is introduced to the filtrate side of cartridge 57 via lines 72, 67, 84, 65 and 66. This pressurises both the lumen side and the shell side of cartridge 57.

In step 2, the flow of high pressure gas is stopped and all valve settings are the same as for step 1 except that valve 81 is open. This releases the pressure inside cartridge 57, removing trapped bubbles of gas from within the fibres. Step 3 is a return to normal filtration.

A modification of the rewetting mode 8 is to introduce the high pressure air on the shell side instead of the filtrate side of cartridge 57. This can be achieved in the following three steps:

In step 1, valves 79, 75, 71, 81 and 62 are closed, valves 63, 56 and 68 are open and high pressure gas is introduced to the shell side of cartridge 57 via lines 82, 50, 54, 55, 64 and 58 to pressurise both the

shell and the lumen sides of cartridge 57.

In step 2 the flow of high pressure gas is stopped. All valve settings are the same as for Step 1 except that valve 79 is open to release the pressure inside cartridge 57 and removes trapped bubbles of gas from within the fibres. Step 3 is a return to normal filtration. The rewetting pressurisation cycle may be performed one or more times.

The combination of the backwash and reversal of the direction of flow produces an effect that is greater than that expected by the addition or superposition of the results of backwashing on the results of reversing the direction of the flow of feed. The result is somewhat unexpected but is possible because the application of the technique, as has been observed in transparent shell cartridges, establishes new flow patterns, thereby reducing the self-increasing effect of blocked cartridges that was discussed earlier. The increased turbulence created by the simultaneous application of the two techniques clears blockages from the cartridge instead of allowing material to build up on previously deposited material.

During the filtering stage where flow is in one direction, there is a small pressure drop in feedstock pressure along the cartridge. This difference in pressure between distal and proximal ends of the cartridge increases during the application of the gaseous backwash. Thus the gas at the distal end of the cartridge faces a lower transmembrane pressure drop than the gas at the proximal end of the cartridge, and more bubbles pass through the fibre walls at the distal end of the cartridge. The reversal of the direction of the flow of feed applied during gaseous backwash reverses the pressure difference effect and allows a more even distribution of bubbles passing through the walls of the fibres.

The relative effectiveness of the liquid and gaseous backwashes and of reversal of the direction of flow of the feedstock depends on the nature of the suspension being filtered. Caking deposits are better removed by gaseous backwash combined with a reversal of direction of flow of feedstock. Indeed it is for such deposits that form clots that the technique is particularly successful when compared with other methods. Backwash alone loosens the retained solids which are then quickly redeposited on the fibres as soon as filtration is recommenced. The application of reversal of direction of flow of feed creates turbulence along the outer walls of the fibres and carries away the clotted solid material.

Fig. 8 shows a modified installation substantially similar to that of Fig. 7 and, as such, most components have been omitted. Feed to the shell 40 is applied through line 41 and a three-way valve 42 to feed inlet 43. Feed is discharged from the shell through feed outlet line 44 having a valve 45. Valve 48 is closed during the filtering operation.

A third port is connected to line 46 leading from the feed inlet valve 42. Discharge line 47 having a valve 48, is connected between the feed inlet 43 and feed outlet line 44 downstream of the discharge valve 45.

With such a filter, the method described in respect of the Fig. 7 installation is modified in that after the release of the pressure on the outer surface of the fibres (i.e. after stage 3 of mode 2), the feed from the pump is directed to the third port through line 46 so as to flush out both ends of the shell or housing through discharge line 47 in the case of the inlet end of the shell and through the normal feed outlet line 44 at the other end of the shell.

In order that the invention may be more readily understood, reference will now be made to the following examples which were carried out using the installation of Fig. 7 suitably manipulated by changing valves, lines and orders of operation to effect the modes indicated.

In all cases, the filter cartridge contained a bundle of about 3,000 polypropylene hollow fibres with feed being applied in a cross-flow fashion to the outer surface of the fibres and filtrate being withdrawn from each end of the fibre lumens. The cartridge end design of Fig. 4 was used in Examples 1 to 6 and 9, that of Fig. 5 was used in Examples 7 and 8 and that of Fig. 6 was used in Examples 10 and 11.

EXAMPLE I: MODES 1(b) (Comparative Mode), 2(b) according to the invention and 4(b) (Comparative Mode)

This experiment was conducted to compare the effectiveness of the normal mode 1(b), the reverse flow mode 2(b), and the pulsed mode 4(b).

A suspension containing ferric hydroxide was made by mixing 360 ml "Ferriclear" and 1080 g sodium hydrogen carbonate in 20 litres water, to precipitate 199.8 g ferric hydroxide.

In the normal mode (1b), the feed inlet pressure was 50 KPa and the feed outlet pressure zero. Air at 600 KPa was blown back for 6 seconds. The total time of the backwash and air removal was 40 seconds. The cycle of mode 1(b) followed by mode 8 was repeated every 10 minutes.

Backwash modes 2(b) and 4(b) were carried out.

After each of the above modes, the filter was subjected to rewetting mode 8.

The three modes may be compared by comparing the filtrate flow rates after 10 minutes, and recovery after air blowback for several consecutive cycles. The results are set forth in Table I where:

1(b) is the normal mode, with lumens not drained

2(b) is the pressure increase with reverse flow of feed mode, with lumens not drained

4(b)) is the pressure increase with pulsing feed outflow mode, with lumens not drained

It can be seen from the following Table I that mode 2(b) recovered the filtrate flow rate (flux) to a higher value than mode 4(b) and that this was in turn more effective than mode 1(b). The results are shown in Fig. 9.

TABLE I

Time Mins	Flux l/hr	Backwash Mode applied after 10 min
0	740	
10	295	1(b)
0	760	
10	300	1(b)
0	750	
10	330	1(b)
0	760	
10	360	1(b)
0	760	
10	360	2(b)
0	900	
10	335	2(b)
0	920	
10	340	2(b)
0	950	
10	300	2(b)
0	950	
10	340	4(b)
0	820	
10	320	4(b)
0	815	
10	345	4(b)
0	810	
10	360	4(b)
0	830	
10	360	Nil

EXAMPLE 2 MODES 1(b) (Comparative Mode), 4(b) (Comparative Mode) and 2(b) (according to the invention)

A mixture of 50g diatomite ("Whitco") and 50g bentonite in 201 water was filtered repeatedly to test the effectiveness of the modes of backwashing. All feed, filtrate and backwashed material was returned to the feed tank. The temperature of the feed was kept constant in the range of 22.5 °C to 26 °C by a copper coil heat exchanger using cold tap water. The modes tested were the normal backwash mode 1(b), the pulsed mode 4(b) and the reverse flow mode 2(b). Each backwash was followed by rewetting sequence mode

The results in which the time taken to apply the backwash has been deleted from the time figures are shown in Table II where:-

1(b) is the normal mode, with lumens not drained

4(b) is the pressure increase with pulsing feed outflow mode, with lumens not drained

2(b) is the pressure increase with reverse flow of feed mode, with lumens not drained

TABLE II

Time (mins)	Flux (l/hr)	Backwash Mode
0	850	
10	420	2(b)
10	840	
20	420	2(b)
20	830	
30	400	2(b)
30	830	
40	420	Nil
0	850	
10	425	1(b)
10	800	
20	405	1(b)
20	780	
30	410	1(b)
30	750	
40	405	Nil
0	850	
10	400	4(b)
10	820	
20	400	4(b)
20	800	
30	395	4(b)
30	800	
40	395	Nil

EXAMPLE 3 Modes 4(b) (Comparative Mode) and 2(b) (according to the invention)

A feedstock consisting of muddy water with a turbidity of 420NTU was used in carrying separate examples in respect of mode 4(b) and mode 2(b) each of which was followed by mode 8. All filtrate and solid material blown off by the backwash was returned to the feed tank. The filtrate at all times was optically clear.

The filtration time between backwashes was 7 minutes. Each backwash took a total of about one and a half minutes to apply, however air only passed through the membrane for ten seconds.

The results are given in the following Tables III and IV and are graphed in Fig. 10.

TABLE III

PRESSURE INCREASE WITH PULSING FEED OUTFLOW MODE (4b)	
Time (mins)	Filtrate Flow Rate (Litres/hour)
0. 7.0	1100 600
Backwash	
8.75 16.0	800 500
Backwash	
17.45 23.25	650 500
Backwash	
25.5 32.0	600 450
Backwash	
33.75 40.5	600 450
Backwash	
42.5 50.0	550 450
Backwash	
52.5	550

TABLE IV

PRESSURE INCREASE WITH REVERSE FLOW OF FEED (Mode 2(b))

Time (mins)	Filtrate Flow Rate (Litres/hour)	Time (mins)	Filtrate Flow Rate (Litres/hour)
60.0	400	Backwash	
Backwash		146.5	800
61.5	600	154.0	550
70.0	450	Backwash	
Backwash		155.25	850
71.75	700	162.0	575
78.5	500	Backwash	
Backwash		163.1	850
79.8	825	170.0	575
87.0	525	Backwash	
Backwash		171.25	850
88.25	800	178.0	575
95.0	525	Backwash	
Backwash		179.0	850
96.25	800	186.0	575
103.0	550	Backwash	
Backwash		187.25	850
104.75	750	194.0	575
112.0	500	Backwash	
Backwash		195.1	850
113.75	750	202.0	575
121.0	550	Backwash	
Backwash		203.0	875
122.25	800	210.0	575
129.0	525	Backwash	
Backwash		211.0	875
130.5	800		
137.0	525		
Backwash			
138.25	850		
145.0	550		

EXAMPLE 4 Mode 1(b) (Comparative mode)

A batch of suspension was made by mixing 48.7g diatomite with 20 litres of water. The temperature of the feed in the tank was maintained at 25 • C plus or minus 0.2 of a degree.

The initial water flux of the cartridge was 650 l/h. The trans membrane pressure was 123KPa, the inlet pressure was 200 KPa, the feed outlet pressure was 100KPa, and the filtrate pressure was 35KPa. After 10 minutes of recycling the suspension through the filter cartridge, the liquid remaining in the feed tank was quite clear and it was concluded that nearly all the diatomite had been deposited on the outside of the fibres.

Air was blown back through the membrane for about 15 seconds in backwash mode 1(b). 3.3 litres of backwash was collected yielding 18.8g of diatomite. The recovery was 38.6%.

Three backwashes were performed with reversal of the direction of the flow of feed during the backwash to remove almost all of the remaining diatomite.

EXAMPLE 5

The investigation of Example 4 was repeated with ferric hydroxide solution of pH7 containing 77.7g ferric hydroxide in 20 litres of water.

The initial water flux of the cartridge was 820 l/h. The feed inlet pressure was 200KPa, the feed outlet was 100KPa and the filtrate pressure was 45KPa. The temperature of the feed in the tank was maintained at 25 • C plus or minus half a degree.

A 20 second backwash was performed in mode 2(b). 6.26 litres of backwash were collected with a ferric hydroxide recovery of 44.2%

EXAMPLE 6 MODE 1(a) (Comparative) FOLLOWED BY MODE 7

Tap water was filtered through three separate tube-in-shell filter cartridges each containing about 1m^2 of polypropylene porous hollow fibres prewetted with alcohol. The conditions of filtration were such as to maintain a trans membrane pressure of 100KPa. The filtrate flow rate, or flux, was measured before an air backwash of mode 1(a) was applied, and again performing a mode 8 rewetting sequence. The fluxes recorded for each cartridge are shown in the Table V.

TABLE V

CARTRIDGE	FLUX BEFORE AIR BACKWASH	FLUX AFTER BACKWASH MODE 1(a)	FLUX AFTER PRESSURISATION MODE 8
1	1000l/hr	230l/hr	1150l/hr
2	1075l/hr	320l/hr	1200l/hr
3	730l/hr	150l/hr	820l/hr

The increased flow after pressurisation compared with the flow before backwash is a result of the removal by backwash of fouling substances that had accumulated on the surface of the membrane and of air blocking the membrane.

EXAMPLE 7 MODE 7

Two new, dry cartridges, similar to those used in Example 7 were separately treated with pressurized water at 600KPa for 2 to 3 seconds and the filtrate flow rate before and after pressurization is shown in the following Table VI.

TABLE VI

CARTRIDGE	FLUX BEFORE MODE 8	FLUX AFTER MODE 8
1	0l/hr	1250l/hr
2	0l/hr	1325l/hr

EXAMPLE 8 MODES 1(a) (Comparative Mode) and 2(a) (according to the invention)

A one square metre MEMTEC cross-flow cartridge filter was run in dead-end mode, i.e. no recirculation. The feed stream was mains tap water having a typical turbidity of 6NTU and pH of 7.5 to 8. All tests were performed at approximately 20 • C. With the feed recirculation valve closed, a pressure regulating valve placed on the feed inlet was adjusted to give a shell-side pressure of 250 KPa(g). Two backwashes were tested with the intervals between backwashes approximately six hours. The backwashes tested were:

1(a) Normal backwash mode

2(a) Pressure increase with reverse flow of feed mode

The results are set out in TABLE VII.

TABLE VII

Case (i) Normal Backwash - Mode 1(a)								
Peak flux recovery after b/w ($l/hr.m^2$)	880	720	660	620	600	580	530	530
Flux after 't' hours of filtration ($l/hr.m^2$)	600	590	540	520	520	480	460	470
Interval between backwashing 't' (hrs)	6	5	6	6	6	6	6	6
Case (ii) Pressure increase with reverse flow of feed - Mode 2(a)								
Peak flux recovery after b/w ($l/hr.m^2$)	1020	1010	960	840	820	820	820	820
Flux after 't' hours of filtration ($l/hr.m^2$)	500	680	600	600	600	600	600	600
Interval between backwashing 't' (hrs)	16	6	8	6	6	6	6	6

The flux decline in each case was fairly linear. Thus an average between starting and finishing flux rates (in one time interval) was thought to be a good basis on which to evaluate each of the above cases.

Reverse flow backwashing was clearly the best method of backwashing. After allowing transient flux increases to die away, an average filtrate flux of approximately 700 $l/hr.m^2$ was maintained.

After allowing transient flux increases to die away with normal backwashing, an average filtrate flux of approximately 500 $l/hr.m^2$ was maintained.

Clearly the reverse flow backwash was about 40% more effective than a normal backwash.

EXAMPLE 9

A suspension of 600g $Ca(OH)_2$ in 18.3 l water was filtered for 15 minutes at 53 °C before application of each backwash mode as shown in Table VIII. The filtrate fluxes before and after backwash are shown in Table VIII.

The inlet pressure of the cartridge was 200 KPa(g), the outlet pressure was 100 KPa(g) and the cross flow rate was about 2,500 litres/hour.

TABLE VIII

BACKWASH MODE	TIME hr.min	Peak flux l/hr	BACKWASH MODE	TIME hr.min	Peak flux l/hr
	0	1600		2.56	1400
	.15	400		3.11	350
1(b)			4(b)		
	.16	1400		3.12	1350
	.31	410		3.27	330
1(b)			3(b)		
	.32	1150		3.28	1450
	.47	350		3.43	350
1(b)			3(b)		
	.48	1100		3.44	1420
	1.03	370		3.59	360
1(b)			3(b)		
	1.04	1200		4.00	1350
	1.19	370		4.15	320
2(b)			3(b)		
	1.20	1400		4.16	1400
	1.35	390		4.31	380
2(b)			5(b)		
	1.36	1550		4.32	1400
	1.51	420		4.47	380
2(b)			5(b)		
	1.52	1450		4.48	1350
	2.07	320		5.03	370
2(b)			5(b)		
	2.08	1500		5.04	1330
	2.23	340		5.19	350
4(b)	2.24	1450		5.20	1400
	2.39	320		5.35	350
4(b)			5(b)		
	2.40	1400		5.36	1400
	2.55	320			
4(b)					

BACKWASH MODE	TIME hr.min	Peak flux l/hr	BACKWASH MODE	TIME hr.min	Peak flux l/hr
	5.36	1400			
				7.16	1350
3(a)			5(a)	7.31	280
	5.52	1300		7.32	1470
	6.07	330		7.47	300
3(a)			5(a)		
	6.08	1400		7.48	1450
	6.23	310			
3(a)					
	6.24	1350			
	6.39	340			
3(a)					
	6.40	1300			
	6.55	310			
4(a)					
	6.56	1300			
	6.11	300			
4(a)					
	6.12	1300			
	6.27	320			
4(a)					
	6.28	1300			
	6.43	350			
4(a)					
	6.44	1350			
	6.59	290			
5(a)					
	7.00	1420			
	7.15	320			
5(a)					

EXAMPLE 10

The same feedstock as Examples 9 was filtered at 30 °C and backwashed after 15 minutes in each case. Table IX shows the volume of backwash material collected and the dry weight of the recovered solids.

TABLE IX

Backwash Mode	b/w material collected (l)	Mass $Ca(OH)_2$ recovered (g)	Recovered material g/l
1(b)	6.3	281.9	44.7

EXAMPLE 11

In this experiment practical conditions limited the volume of feed, which was therefore recycled through the filter. Clots formed as material was backwashed and blown back into the feed tank where they settled to the bottom and no longer took part in the experiment. This resulted in a steady increase in the minimum flux value after a set interval of time has elapsed after application of the backwash.

A tube in shell cartridge containing microporous polypropylene hollow fibres with approximately 1m² of filtering area was used to filter a suspension containing 50g Bentonite and 50g Diatomaceous Earth in 20 litres of water. The suspension was applied to the outer surface of the fibres. The initial filtrate flux was 900 l/hr. After 10 minutes the flux had fallen to 200 l/hr.

A backwash mode 1(b) was applied for 30 seconds. The 10 minute cycle was repeated 5 times, and each time the flux dropped to 200 l/hr to 250 l/hr before backwash, and rose to 600 l/hr after backwash. The point to which the flux dropped after each cycle was a little higher each time and clots of solid material could be observed in the material discharged during the backwash cycle. The results are graphed in Fig. 11.

Backwashes of mode 2(b) were applied at the end of 10 minute cycles on the same system. Each time the procedure was repeated the flux rose to 900 l/hr.

At the conclusion of the mode 2(b) series of backwash a backwash of mode 1(b) was again performed. The flux again rose to 600 l/hr after the backwash cycle. The results are graphed in Fig. 12.

Fig. 13 shows four cycles of reversed feedstock flows without any backwashing followed by a backwash of mode 2(b). The reversal of direction of flow by itself gives little improvement in flux. The combination of reversing the direction of flow, together with the backwash mode 1(b) gives a cleaning effect greater than the addition of the two separate techniques.

Claims

1. A method of operating a filter (10) having elastic, porous hollow fibres (12) within a tubular shell or housing (11; 40) having a first port adjacent one end of the tubular shell or housing (11; 40) and a second port adjacent the other end of the tubular shell or housing (11; 40), one of said ports serving as a feed inlet (15; 43) to the shell or housing (11; 40) and the other of said ports serving as a feed outlet (17; 44) from the shell or housing (11; 40), said shell or housing (11; 40) optionally having a third port (46) intermediate the feed inlet (43) and the feed outlet (44), the method comprising the steps of:

(i) introducing a liquid suspension feedstock through the feed inlet (15; 43) to the shell or housing (11; 40) and directing said feedstock to the outer surface of the fibres (12) whereby:

a) some of said feedstock passes through the walls of the fibres (12) to be drawn from the fibre lumens as a filtrate or permeate; and

b) some of the solids in said feedstock are retained on or in the pores of the fibres (12), with the non-retained solids being discharged through the feed outlet (17; 44) from the shell or housing (11; 40) with the remainder of said feedstock, and

(ii) periodically cleaning away the retained solids by steps including:

A) introducing a pressurized gas into the fibre lumens while liquid is flowing through the shell or housing (11; 40), said pressurized gas being at a pressure sufficient to cause the gas to pass through the walls of the fibres (12) against the pressure ("the normal gaseous cleaning pressure") then prevailing on the shell side with liquid flowing,

B) then, while maintaining pressurised gas flow into the fibre lumens, <u>either</u> increasing the shell side pressure above the normal gaseous cleaning pressure by stopping outflow of liquid from the shell or housing (11; 40), <u>or</u> decreasing the shell side pressure below the normal gaseous cleaning pressure by stopping inflow of liquid to the shell or housing (11; 40); and

C) thereafter returning to the normal gaseous cleaning pressure by resuming flow of liquid through the shell or housing (11; 40) in a reverse direction.

2. A method according to claim 1, in which the fibres are microporous fibres and, prior to introduction of the pressurised gas, a pressurised liquid is introduced through the fibre lumens and passes through the walls of the fibres (12) to wash out at least some of the retained solids and in which the pressurized gas is applied at a pressure which is sufficient to stretch elastically at least some of the pores in the walls of the fibres (12) to dislodge any solids retained in those pores and to wash the external walls of the fibres (12) and which is sufficient to overcome the resistance to gas flow of the surface tension of the continuous phase of the filtrate within the pores of the fibres (12).

3. A method according to claim 1 or claim 2, which includes the preliminary steps of:
(a) initially applying the gas at a pressure below the bubble point of the walls of the fibres (12) so as to displace any liquid from the fibre lumens,
(b) terminating feed inflow and outflow by closing the feed inlet to and the feed outlet from the shell or housing (11; 40),
(c) increasing the pressure of the gas above the bubble point of the walls of the fibres (12), and
(d) recommencing feed inflow and outflow by opening the feed inlet and feed outlet to allow the gas to escape substantially uniformly through the fibre walls.

4. A method according to any one of claims 1 to 3, in which steps A) to C) are repeated one or more times.

5. A method according to any one of claims 1 to 4, which includes the step of pressurising the fibres (12), after completing steps A) to C) or after the last repetition of steps A) to C), and then releasing the pressure to remove trapped gas from the pores of the fibres (12).

6. A method according to claim 5, in which the step of pressurising the fibres (12) is carried out whilst lumen flow is blocked.

7. A method according to claim 6, in which the lumen flow is blocked in a pulsing fashion.

8. A method according to any one of claims 6 or 7, in which the step of pressurising the fibres (12) is carried out by applying an hydraulic pressure to the feed side of the fibres (12).

9. A method according to any one of the preceding claims, in which the fibre lumens are drained before commencement of steps A) to C).

10. A method according to any one of the preceding claims, in which the shell or housing (11; 40) is drained before commencement of backwash.

11. A method according to any one of the preceding claims, in which the filter (10) is operated as a cross-flow filter.

12. A method according to any one of claims 1 to 10, in which the filter is operated in a dead-end filtering mode with no outflow of feed and solids from the shell or housing (11) during the dead-end filtration.

13. A filter system (10) comprising:
(a) a tubular shell or housing (11; 40),
(b) a plurality of elastic, porous hollow fibres (12) within the shell or housing (11; 40),
(c) a first port adjacent to one end of the shell or housing (11; 40),
(d) a second port adjacent to the other end of the shell or housing (11; 40),
(e) a filtrate outlet (16) from the shell or housing (11) communicating with the lumens of the fibres (12),
(f) shell inlet valve means (63, 42) for introducing a liquid suspension feedstock through one of said first and second ports as a feed inlet (15; 43) to the shell or housing (11; 40) and for directing said feedstock to the outer surface of the fibres (12) whereby:
(i) some of said feedstock passes through the walls of the fibres (12) to be drawn from the fibre lumens as a filtrate or permeate and to be discharged through the filtrate outlet (16), and
(ii) some of the solids in said feedstock are retained on or in the pores of the fibres (12), with the non-retained solids being discharged through the other of said first and second ports as a feed

outlet (17; 44) from the shell or housing (11) with the remainder of said feedstock,
(g) shell outlet valve means (62, 79, 45) for controlling the outflow through the shell outlet (17; 44),
(h) gas control valve means (73) for introducing a pressurized gas into the fibre lumens with liquid flow through the shell side of the fibre walls at a pressure sufficient to cause the gas to pass through the walls of the fibres (12) against the pressure ("the normal gaseous cleaning pressure") then prevailing with liquid flow through the shell side thereby to cause gas to pass through the walls of the fibres (12) to dislodge retained solids,
(i) valve means (56, 75; 42) for reversing the flow of feedstock through the shell, and
(j) control means for varying the pressure within the shell or housing (11; 40), whilst the gas is being introduced into the lumens, said control means being adapted either

- to actuate the shell outlet valve means (62, 79; 45) to increase the pressure within the shell or housing (11; 40) on the shell side of the fibre walls above the normal gaseous cleaning pressure by stopping outflow of liquid from the shell or housing (11; 40) through the shell outlet (17; 44); or
- to actuate the shell inlet valve means (63; 42) to decrease the pressure within the shell or housing (11; 40) on the shell side of the fibre walls below the normal gaseous cleaning pressure by stopping inflow of liquid to the shell or housing (11; 40) through the shell inlet (15; 43); said control means further being adapted to actuate said flow reverse valve means (56, 75; 42) to then return the pressure within the shell or housing (11; 40) on the shell side of the fibre walls to the normal cleaning pressure by resuming flow of liquid through the shell or housing (11; 40) in a reverse direction whereby said one port now becomes the feed outlet (17; 44) and said other port now becomes the feed inlet (15; 43).

14. A filter system according to claim 13, which includes valve means (71) for closing off the filtrate flow.

15. A filter system according to claim 13 or claim 14, in which a third port (46) is provided intermediate between the feed inlet (43) and the feed outlet (44), in which the shell inlet valve means comprise a three-way valve (42), which is provided to direct feed temporarily to the third port (46), and in which a further valve (48) is provided to permit temporary outflow from the feed inlet (43) as well as from the feed outlet (44).

Patentansprüche

1. Verfahren zum Betreiben eines Filters (10), der elastische, poröse Hohlfasern (12) innerhalb eines rohrförmigen Mantels oder Gehäuses (11; 40) aufweist, der bzw. das eine erste Öffnung nahe dem einen Ende des rohrförmigen Mantels oder Gehäuses (11; 40) und eine zweite Öffnung nahe dem anderen Ende des rohrförmigen Mantels oder Gehäuses (11; 40) aufweist, wobei eine der genannten Öffnungen als Aufgabegut-Einlaß (15; 43) zu dem Mantel oder dem Gehäuse (11; 40) dient und die andere der genannten Öffnungen als ein Aufgabegut-Auslaß (17; 44) aus dem Mantel oder Gehäuse (11; 40) dient, der genannte Mantel oder das genannte Gehäuse (11; 40) wahlweise eine dritte Öffnung (46) zwischen dem Aufgabegut-Einlaß (43) und dem Aufgabegut-Auslaß (44) aufweist, und das Verfahren die folgenden Schritte aufweist:
(i) Einleiten eines aus einer flüssigen Suspension gebildeten Ausgangsmaterials durch den Aufgabegut-Einlaß (15; 43) zum Mantel oder Gehäuse (11; 40) und Lenken des genannten Ausgangsmaterials zur äußeren Oberfläche der Fasern (12), wodurch:
a) ein Anteil des genannten Ausgangsmaterials durch die Wände der Fasern (12) hindurchtritt, um aus den Faser-Hohlräumen als Filtrat oder durchgedrungenes Material bzw. Permeat abgesaugt zu werden; und
b) einige der Feststoffe im genannten Ausgangsmaterial an oder in den Poren der Fasern (12) zurückgehalten werden, wobei die nicht-zurückgehaltenen Feststoffe durch den Aufgabegut-Auslaß (17; 44) aus dem Mantel oder dem Gehäuse (11; 40) zusammen mit dem Rest des Ausgangsmaterials abgegeben werden; und
(ii) periodisches, reinigendes Entfernen der zurückgehaltenen Feststoffe durch Schritte, die die folgenden umfassen:
A) Einleiten eines Druckgases in die Faser-Hohlräume, während Flüssigkeit durch den Mantel oder das Gehäuse (11; 40) strömt, wobei das genannte Druckgas sich bei einem Druck befindet, der ausreicht, um das Gas zu veranlassen, durch die Wände der Fasern (12) gegen den Druck ("den normalen Gas-Reinigungsdruck") hindurchzutreten, der auf der Mantelseite dann vor-

herrscht, während die Flüssigkeit strömt;
B) dann, während man den Druckgasstrom in die Faser-Hohlräume aufrechterhält, entweder Erhöhen des mantelseitigen Drucks über den normalen Gas-Reinigungsdruck durch Abbrechen der Ausströmung der Flüssigkeit aus dem Mantel oder Gehäuse (11; 40), oder Vermindern des mantelseitigen Drucks unter den normalen Gas-Reinigungsdruck durch Abbrechen der Einströmung der Flüssigkeit zum Mantel oder Gehäuse (11; 40);
und
c) nachfolgend Zurückkehren zum normalen Gas-Reinigungsdruck durch Wiederaufnahme des Flüssigkeitsstromes durch den Mantel oder das Gehäuse (11; 40) in umgekehrter Richtung.

2. Verfahren nach Anspruch 1, worin die Fasern mikroporöse Fasern sind und vor dem Einleiten des Druckgases eine Druckflüssigkeit durch die Faser-Hohlräume eingeleitet wird und die Wände der Fasern (12) durchdringt, um mindestens einige der zurückgehaltenen Feststoffe auszuspülen, und worin das Druckgas unter einem Druck angelegt wird, der ausreicht, um mindestens einige der Poren in den Wänden der Fasern (12) elastisch zu dehnen, um irgendwelche Feststoffe, die in diesen Poren zurückgehalten sind, zu entfernen und die Außenwände der Fasern (12) zu spülen, und der ausreicht, um den Widerstand der Oberflächenspannung der kontinuierlichen Phase des Filtrats innerhalb der Poren der Fasern (12) gegenüber der Gasströmung zu überwinden.

3. Verfahren nach Anspruch 1 oder Anspruch 2, das die folgenden, vorbereitenden Schritte aufweist:
(a) anfängliches Anlegen des Gases unter einen Druck unter dem Blasenpunkt der Wände der Fasern (12), um jegliche Flüssigkeit aus den Faser-Hohlräumen zu verdrängen,
(b) Beenden der Ein- und Ausströmung des Aufgabegutes durch Schließen des Aufgabegut-Einlasses zum Mantel oder Gehäuse (11; 40) und des Aufgabegut-Auslasses aus dem Mantel oder Gehäuse,
(c) Erhöhen des Gasdrucks über den Blasenpunkt der Wände der Fasern (12), und
(d) Wiederaufnahme der Ein- und Ausströmung des Aufgabegutes durch Öffnen des Aufgabegut-Einlasses und des Aufgabegut-Auslasses, um es dem Gas zu ermöglichen, im wesentlichen gleichförmig durch die Faserwände zu entweichen.

4. Verfahren nach irgendeinem der Ansprüche 1 bis 3, worin die Schritte A) bis C) einmal oder mehrfach wiederholt werden.

5. Verfahren nach irgendeinem der Ansprüche 1 bis 4, das den Schritt der Druckbeaufschlagung der Fasern (12) nach Fertigstellung der Schritte A) bis C) oder nach der letzten Wiederholung der Schritte A) bis C) und dann der Druckentlastung umfaßt, um eingeschlossenes Gas aus den Poren der Fasern (12) zu entfernen.

6. Verfahren nach Anspruch 5, worin der Schritt der Druckbeaufschlagung der Fasern (12) ausgeführt wird, während die Hohlraumströmung gesperrt wird.

7. Verfahren nach Anspruch 6, worin die Hohlraumströmung auf pulsierende Weise gesperrt wird.

8. Verfahren nach irgendeinem der Ansprüche 6 oder 7, worin der Schritt der Druckbeaufschlagung der Fasern (12) dadurch ausgeführt wird, daß man einen hydraulischen Druck auf der Einspeisungsseite der Fasern (12) anlegt.

9. Verfahren nach irgendeinem der vorangehenden Ansprüche, worin die Faser-Hohlräume vor dem Beginn der Schritte A) bis C) trockengelegt werden.

10. Verfahren nach irgendeinem der vorangehenden Ansprüche, worin der Mantel oder das Gehäuse (11; 40) vor dem Beginn der Gegenspülung trockengelegt wird.

11. Verfahren nach irgendeinem der vorangehenden Ansprüche, worin das Filter (10) als Querströmungsfilter betrieben wird.

12. Verfahren nach irgendeinem der Ansprüche 1 bis 10, worin das Filter in einem Sack- oder End-Filtrierungsbetrieb betrieben wird, wobei keine Ausströmung des Aufgabematerials und der Feststoffe

aus dem Mantel oder Gehäuse (11) während der Sack-Filtrierung stattfindet.

13. Filtersystem (10), mit:
(a) einem rohrförmigen Mantel oder Gehäuse (11; 40),
(b) einer Anzahl von elastischen, porösen Hohlfasern (12) innerhalb des Mantels oder Gehäuses (11; 40),
(c) einer ersten Öffnung nahe dem einen Ende des Mantels oder Gehäuses (11; 40),
(d) einer zweiten Öffnung nahe dem anderen Ende des Mantels oder Gehäuses (11; 40),
(e) einem Filtratauslaß (16) aus dem Mantel oder Gehäuse (11), der mit den Hohlräumen der Fasern (12) in Verbindung steht,
(f) einer Manteleinlaß-Ventileinrichtung (63; 42) zum Einleiten eines Ausgangsmaterials aus einer flüssigen Suspension durch eine der genannten ersten und zweiten Öffnungen als ein Aufgabegut-Einlaß (15; 43) zum Mantel oder Gehäuse (11; 40) und zum Lenken des genannten Ausgangsmaterials zur Außenoberfläche der Fasern (12), wodurch:
(i) ein Anteil des genannten Ausgangsmaterials durch die Wände der Fasern (12) hindurchtritt, um von den Faser-Hohlräumen als ein Filtrat oder Permeat abgezogen zu werden und um durch den Filtratauslaß (16) hindurch abgegeben zu werden, und
(ii) ein Anteil der Feststoffe im genannten Ausgangsmaterial an oder in den Poren der Fasern (12) zurückgehalten wird, wobei die nicht-zurückgehaltenen Feststoffe durch die andere der genannten ersten und zweiten Öffnung als ein Aufgabegut-Auslaß (17; 44) aus dem Mantel oder Gehäuse (11) zusammen mit dem Rest des genannten Ausgangsmaterials abgegeben werden,
(g) einer Mantelauslaß-Ventileinrichtung (62, 79; 45) zum Steuern der Strömung durch den Mantelauslaß (17; 44) nach außen,
(h) einer Gas-Steuerventileinrichtung (73) zum Einleiten eines Druckgases in die Faser-Hohlräume, mit einer Flüssigkeitsströmung durch die Mantelseite der Faserwände mit einem Druck, der ausreicht, um das Gas zu veranlassen, durch die Wände der Fasern (12) gegen den Druck ("den normalen Gas-Reinigungsdruck") hindurchzutreten, der dann mit der Flüssigkeitsströmung durch die Mantelseite vorliegt, um hierdurch Gas zu veranlassen, durch die Wände der Fasern (12) hindurchzutreten, um zurückgehaltene Feststoffe zu entfernen,
(i) einer Ventileinrichtung (56, 75; 42) zum Umkehren der Strömung des Ausgangsmaterials durch den Mantel, und
(j) Steuermitteln zum Ändern des Drucks innerhalb des Mantels oder Gehäuses (11; 40), während das Gas in die Hohlräume eingeleitet wird, wobei die genannten Steuermittel dazu eingerichtet sind, entweder
- die Mantelauslaß-Ventileinrichtung (62, 79; 45) zu betätigen, um den Druck innerhalb des Mantels oder Gehäuses (11; 40) auf der Mantelseite der Faserwände über den normalen Gas-Reinigungsdruck durch Abbrechen der Flüssigkeitsströmung aus dem Mantel oder Gehäuse (11; 40) durch den Mantel (17; 44) nach außen zu erhöhen;
oder
- die Manteleinlaß-Ventileinrichtung (63; 42) zu betätigen, um den Druck innerhalb des Mantels oder Gehäuses (11; 40) auf der Mantelseite der Faserwände unter den normalen Gas-Reinigungsdruck dadurch abzusenken, daß die Flüssigkeitsströmung zum Mantel oder Gehäuse (11; 40) durch den Manteleinlaß (15; 43) hinein abgebrochen wird; wobei die genannten Steuermittel ferner dazu eingerichtet sind, die genannte Strömungs-Umkehr-Ventileinrichtung (56, 75; 42) zu betätigen, um dann den Druck innerhalb des Mantels oder Gehäuses (11; 40) auf der Mantelseite der Faserwände auf den normalen Reinigungsdruck dadurch zurückzubringen, daß die Flüssigkeitsströmung durch den Mantel oder das Gehäuse (11; 40) in umgekehrter Richtung wieder aufgenommen wird, wodurch die genannte eine Öffnung nun der Aufgabegut-Auslaß (17; 44) wird und die genannte andere Öffnung nun der Aufgabegut-Einlaß (15; 43) wird.

14. Filtersystem nach Anspruch 13, das eine Ventileinrichtung (71) zum Absperren des Filtratstroms aufweist.

15. Filtersystem nach Anspruch 13 oder Anspruch 14, worin eine dritte Öffnung (46) zwischen dem Aufgabegut-Einlaß (43) und dem Aufgabegut-Auslaß (44) vorgesehen ist, worin die Manteleinlaß-Ventileinrichtung ein Dreiwegeventil (42) aufweist, das vorgesehen ist, um das Aufgabegut zeitweise zur dritten Öffnung (46) zu lenken, und worin ein weiteres Ventil (48) vorgesehen ist, um die zeitweilige

Strömung aus dem Aufgabegut-Einlaß (43) sowie aus dem Aufgabegut-Auslaß (44) zu gestatten.

Revendications

1. Procédé pour utiliser un filtre (10) comportant des fibres creuses poreuses élastiques (12) à l'intérieur d'une enveloppe ou boîtier tubulaire (11; 40) ayant un premier orifice adjacent à une extrémité de l'enveloppe ou boîtier tubulaire (11; 40) et un second orifice adjacent à l'autre extrémité de l'enveloppe ou boîtier tubulaire (11; 40), l'un desdits orifices servant d'entrée de charge (15; 43) de l'enveloppe ou boîtier (11; 40) et l'autre desdits orifices servant de sortie de charge (17; 44) de l'enveloppe ou boîtier (11; 40), ladite enveloppe ou ledit boîtier (11; 40) ayant éventuellement un troisième orifice (46) en position intermédiaire par rapport à l'entrée de charge (43) et à la sortie de charge (44), le procédé comprenant les étapes consistant à :
   (i) introduire une charge en suspension liquide dans l'enveloppe ou boîtier (11; 40) par l'entrée de charge (15; 43) et diriger ladite charge vers la surface externe des fibres (12) de sorte que :
      (a) une certaine partie de ladite charge traverse les parois des fibres (12) pour être entraînée dans les ouvertures des fibres sous forme de filtrat ou perméat; et
      (b) une certaine partie des solides de ladite charge sont retenus sur ou dans les pores des fibres (12), les solides non retenus étant évacués de l'enveloppe ou boîtier (11; 40) par la sortie de charge (17; 44) avec le reste de ladite charge; et
   (ii) éliminer périodiquement par nettoyage les solides retenus par des étapes consistant à:
      (A) introduire un gaz sous pression dans les ouvertures des fibres tandis que du liquide s'écoule dans l'enveloppe ou boîtier (11; 40), ledit gaz sous pression étant à une pression suffisante pour amener le gaz à traverser les parois des fibres (12) à l'encontre de la pression ("la pression de nettoyage gazeuse normale") qui règne alors du côté enveloppe avec l'écoulement de liquide;
      (B) puis, tout en maintenant l'écoulement de gaz sous pression dans les ouvertures des fibres, augmenter la pression du côté enveloppe au dessus de la pression de nettoyage gazeuse normale en interrompant l'écoulement sortant de liquide de l'enveloppe ou boîtier (11; 40), ou abaisser la pression du côté enveloppe au-dessous de la pression de nettoyage gazeuse normale en interrompant l'écoulement entrant de liquide dans l'enveloppe ou boîtier (11; 40); et
      (C) revenir ensuite à la pression de nettoyage gazeuse normale en rétablissant l'écoulement de liquide dans l'enveloppe ou boîtier (11; 40) en sens inverse.

2. Procédé selon la revendication 1, dans lequel les fibres sont des fibres microporeuses et, avant l'introduction du gaz sous pression, un liquide sous pression est introduit par les ouvertures des fibres et traverse les parois des fibres (12) pour éliminer par lavage au moins certains des solides retenus et dans lequel le gaz sous pression est appliqué à une pression qui est suffisante pour dilater élastiquement au moins certains des pores des parois des fibres (12) pour déloger tous les solides retenus dans ces pores et pour laver les parois externes des fibres (12) et qui est suffisante pour vaincre la résistance à l'écoulement du gaz de la tension superficielle de la phase continue du filtrat à l'intérieur des pores des fibres (12).

3. Procédé selon la revendication 1 ou la revendication 2, qui comprend les étapes préliminaires consistant à:
   (a) appliquer initialement le gaz à une pression inférieure au point de bulle des parois des fibres (12) de manière à déplacer tout liquide des ouvertures des fibres,
   (b) interrompre l'écoulement de charge entrant et l'écoulement de charge sortant en fermant l'entrée de charge et la sortie de charge de l'enveloppe ou boîtier (11; 40),
   (c) augmenter la pression du gaz au dessus du point de bulle des parois des fibres (12), et
   (d) rétablir l'écoulement de charge entrant et l'écoulement de charge sortant en ouvrant l'entrée de charge et la sortie de charge pour permettre au gaz de s'échapper de manière sensiblement uniforme à travers les parois des fibres.

4. Procédé selon l'une quelconque des revendications 1 à 3, dans lequel les étapes (A) à (C) sont répétées une ou plusieurs fois.

5. Procédé selon l'une quelconque des revendications 1 à 4, qui comprend l'étape consistant à mettre sous pression les fibres (12), après l'achèvement des étapes (A) à (C) ou après la dernière répétition des étapes (A) à (C), puis à relâcher la pression pour retirer le gaz piégé des pores des fibres (12).

6. Procédé selon la revendication 5, dans lequel l'étape de mise sous pression des fibres (12) est accomplie tandis que l'écoulement dans les ouvertures est bloqué.

7. Procédé selon la revendication 6, dans lequel l'écoulement dans les ouvertures est bloqué de manière pulsée.

8. Procédé selon l'une quelconque des revendications 6 ou 7, dans lequel l'étape de mise sous pression des fibres (12) est accomplie par application d'une pression hydraulique du côté alimentation des fibres (12).

9. Procédé selon l'une quelconque des revendications précédentes, dans lequel les ouvertures des fibres sont drainées avant le commencement des étapes (A) à (C).

10. Procédé selon l'une quelconque des revendications précédentes, dans lequel l'enveloppe ou boîtier (11; 40) est drainée avant le commencement du lavage à contre-courant.

11. Procédé selon l'une quelconque des revendications précédentes, dans lequel le filtre (10) est utilisé sous forme de filtre à courant transversal.

12. Procédé selon l'une quelconque des revendications 1 à 10, dans lequel le filtre est utilisé dans un mode de filtration en cul-de-sac sans écoulement sortant de la charge et des solides depuis l'enveloppe ou boîtier (11) au cours de la filtration en cul-de-sac.

13. Système de filtre (10) comprenant:

(a) une enveloppe ou boîtier tubulaire (11; 40),

(b) une multiplicité de fibres creuses poreuses élastiques (12) à l'intérieur de l'enveloppe ou boîtier (11; 40),

(c) un premier orifice adjacent à une extrémité de l'enveloppe ou boîtier (11; 40),

(d) un second orifice adjacent à l'autre extrémité de l'enveloppe ou boîtier (11; 40),

(e) une sortie de filtrat (16) de l'enveloppe ou boîtier (11) qui communique avec les ouvertures des fibres (12),

(f) des dispositifs formant vannes d'entrée d'enveloppe (63; 42) pour introduire une charge en suspension liquide par l'un desdits premier et second orifices sous forme d'entrée de charge (15; 43) de l'enveloppe ou boîtier (11; 40) et pour diriger ladite charge vers la surface externe des fibres (12) de sorte que:

(i) une certaine partie de ladite charge traverse les parois des fibres (12) pour être entraînée dans les ouvertures des fibres sous forme de filtrat ou perméat et pour être évacuée par la sortie de filtrat (16), et

(ii) une certaine partie des solides de ladite charge sont retenus sur ou dans les pores des fibres (12), les solides non retenus étant évacués par l'autre desdits premier et second orifices sous forme de sortie de charge (17; 44) de l'enveloppe ou boîtier (11) avec le reste de ladite charge,

(g) des dispositifs formant vannes de sortie d'enveloppe (62, 79; 45) pour commander l'écoulement sortant par la sortie d'enveloppe (17; 44),

(h) des dispositifs formant vannes de commande (73) pour introduire un gaz sous pression dans les ouvertures des fibres avec un écoulement de liquide du côté enveloppe des parois des fibres à une pression suffisante pour amener le gaz à traverser les parois des fibres (12) à l'encontre de la pression ("la pression de nettoyage gazeuse normale") qui règne alors avec l'écoulement de liquide du côté enveloppe de manière a amener le gaz à traverser les parois des fibres (12) pour déloger les solides retenus,

(i) des dispositifs formant vannes (56, 75; 42) pour inverser l'écoulement de charge dans l'enveloppe, et

(j) des dispositifs de commande pour modifier la pression à l'intérieur de l'enveloppe ou boîtier (11; 40) tandis que le gaz est introduit dans les ouvertures, lesdits dispositifs de commande étant conçus soit

- pour actionner les dispositifs formant vannes de sortie d'enveloppe (62, 79; 45) pour augmenter la pression dans l'enveloppe ou boîtier (11; 40) du côté enveloppe des parois des fibres au dessus de la pression de nettoyage gazeuse normale par interruption de l'écoulement sortant de liquide de l'enveloppe ou boîtier (11; 40) par la sortie d'enveloppe (17; 44);

soit

- pour actionner les dispositifs formant vannes d'entrée d'enveloppe (63; 42) pour abaisser la pression dans l'enveloppe ou boîtier (11; 40) du côté enveloppe des parois des fibres au-dessous de la pression de nettoyage gazeuse normale par interruption de l'écoulement entrant de liquide dans l'enveloppe ou boîtier (11; 40) par l'entrée d'enveloppe (15; 43);

lesdits dispositifs de commande étant conçus en outre pour actionner lesdits dispositifs formant vannes d'inversion d'écoulement (56, 75; 42) pour ramener alors la pression à l'intérieur de l'enveloppe ou boîtier (11; 40) du côté enveloppe des parois des fibres à la pression de nettoyage normale par rétablissement de l'écoulement de liquide dans l'enveloppe ou boîtier (11; 40) en sens inverse de sorte que ledit premier orifice devient maintenant la sortie de charge (17; 44) et que ledit second orifice devient maintenant l'entrée de charge (15; 43).

14. Système de filtre selon la revendication 13, qui comprend un dispositif formant vanne (71) pour interrompre l'écoulement de filtrat.

15. Système de filtre selon la revendication 13 ou la revendication 14, dans lequel un troisième orifice (46) est prévu en position intermédiaire entre l'entrée de charge (43) et la sortie de charge (44), dans lequel les dispositifs formant vannes d'entrée d'enveloppe comprennent une vanne trois voies (42) qui est prévue pour diriger temporairement la charge vers le troisième orifice (46), et dans lequel une autre vanne (48) est prévue pour permettre un écoulement sortant temporaire depuis l'entrée de charge (43) ainsi que depuis la sortie de charge (44).

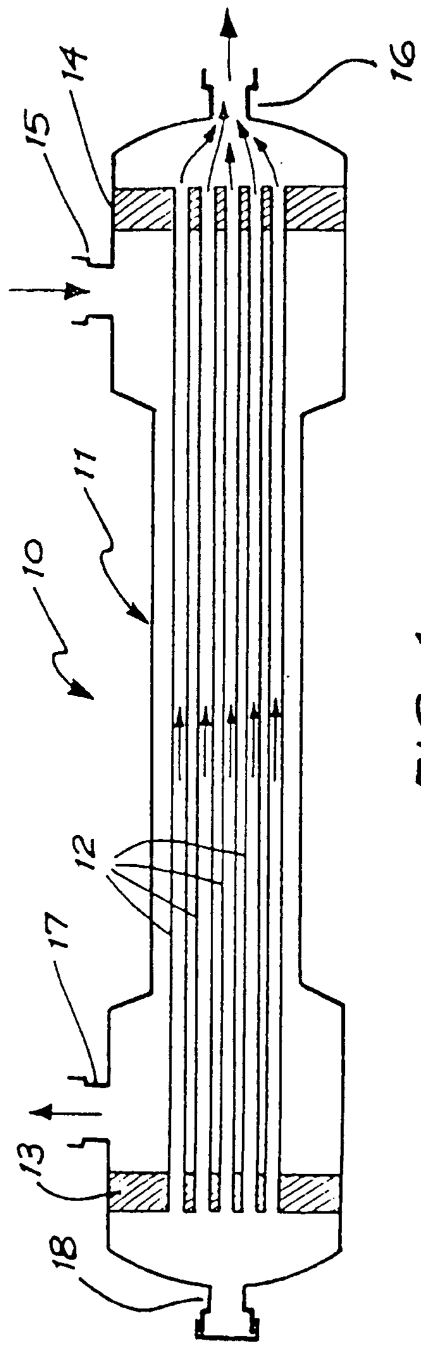


FIG. 1

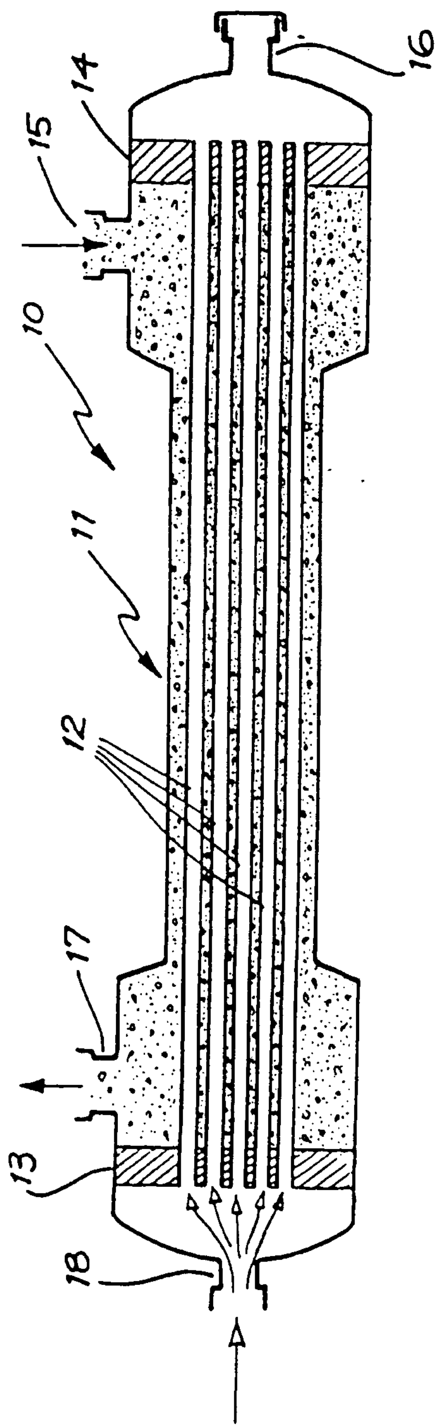


FIG. 2

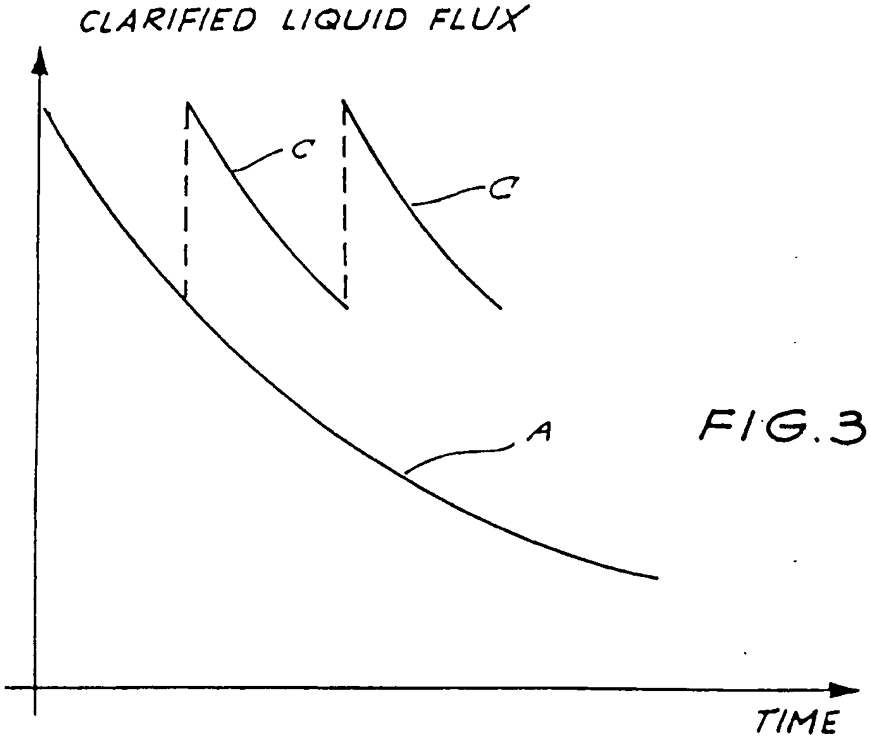


FIG.3

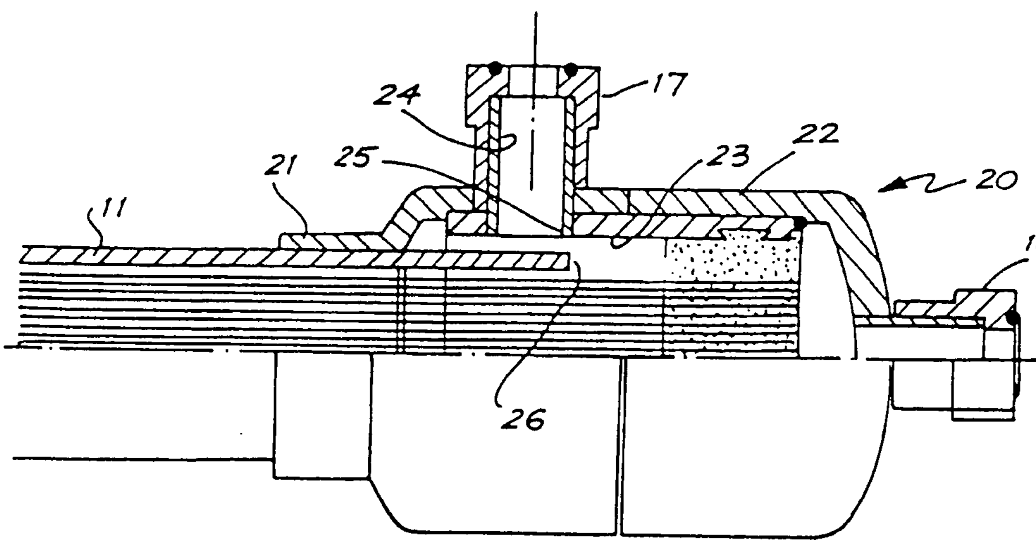


FIG.4

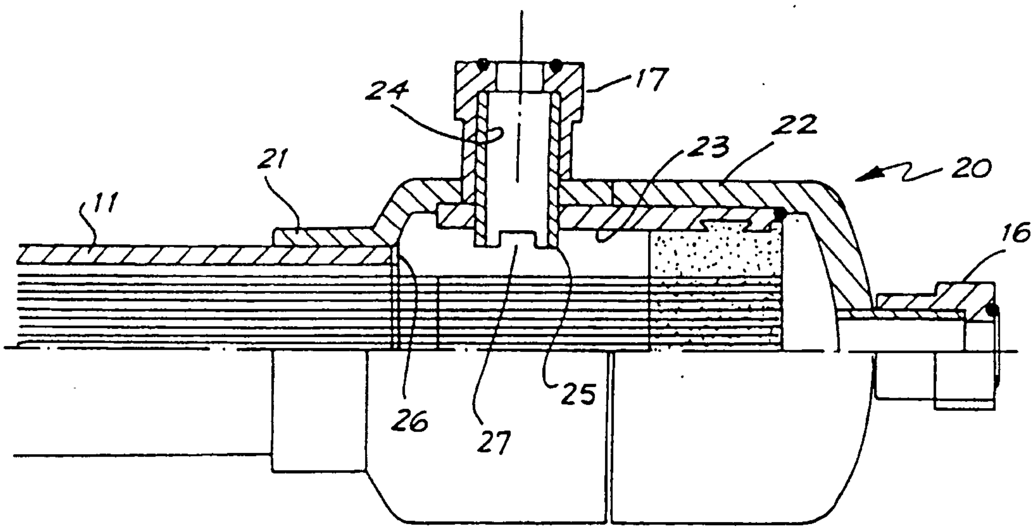


FIG. 5

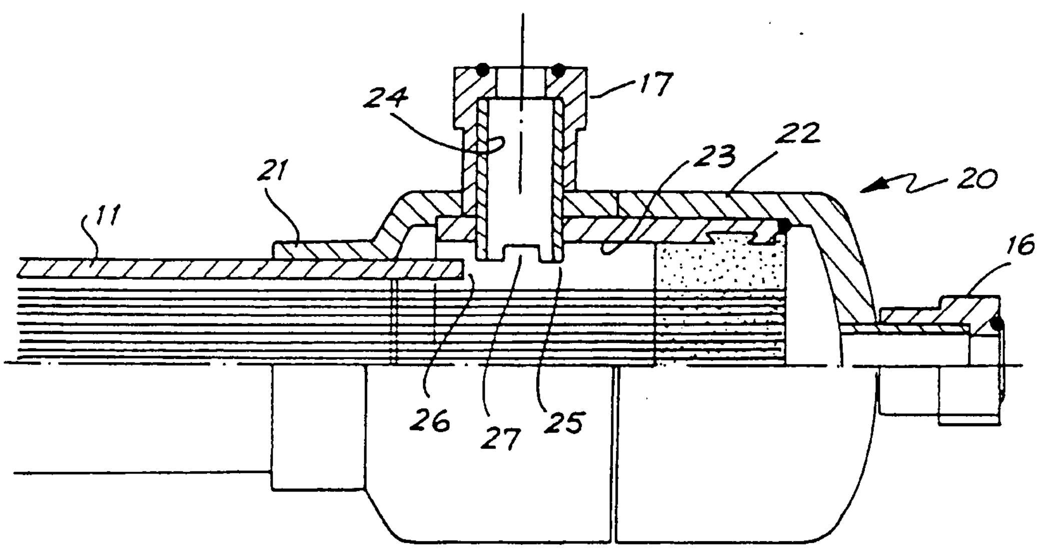
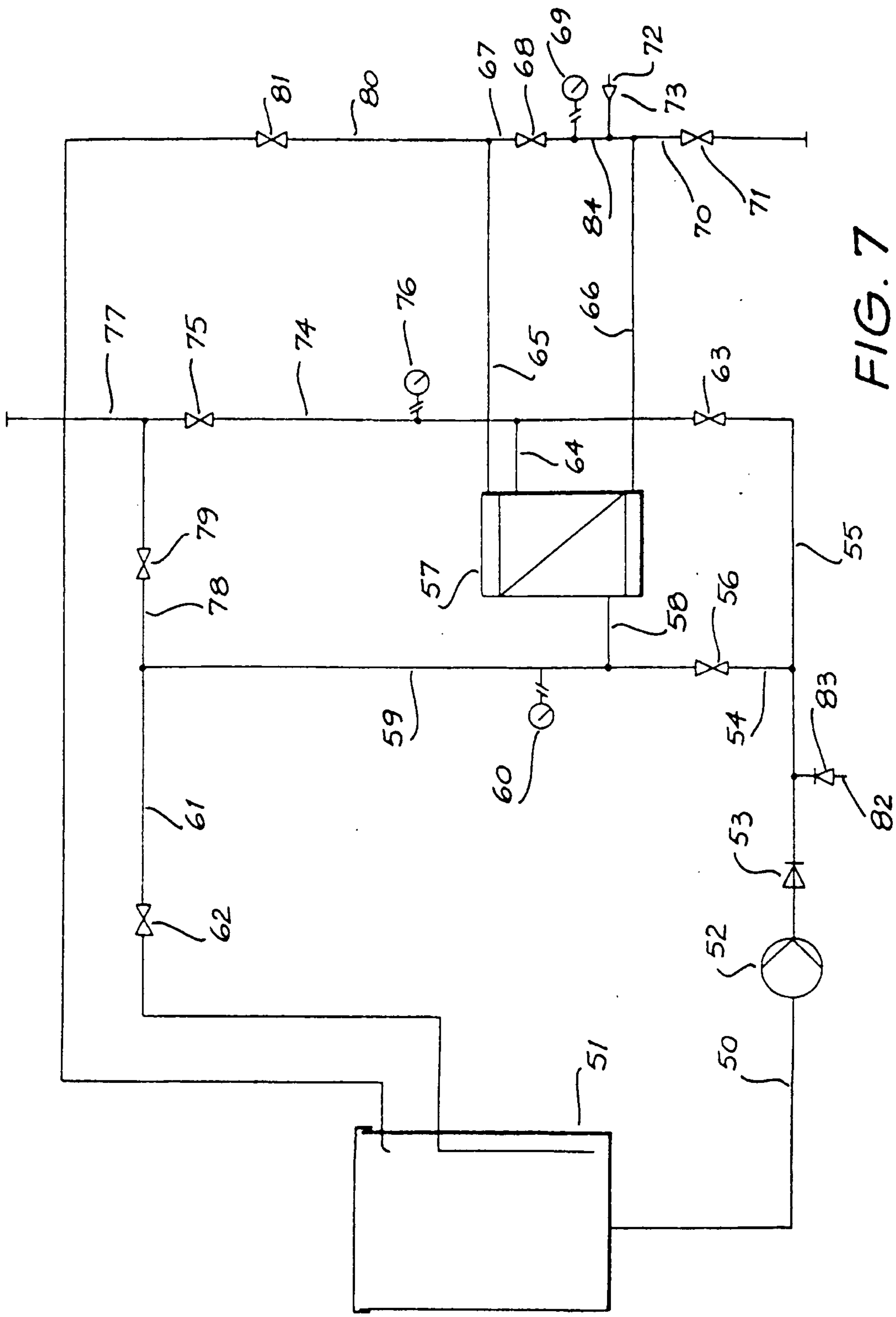


FIG. 6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70
71
72
73
74
75
76
77
78
79
80
81
82
83
84

FIG. 7

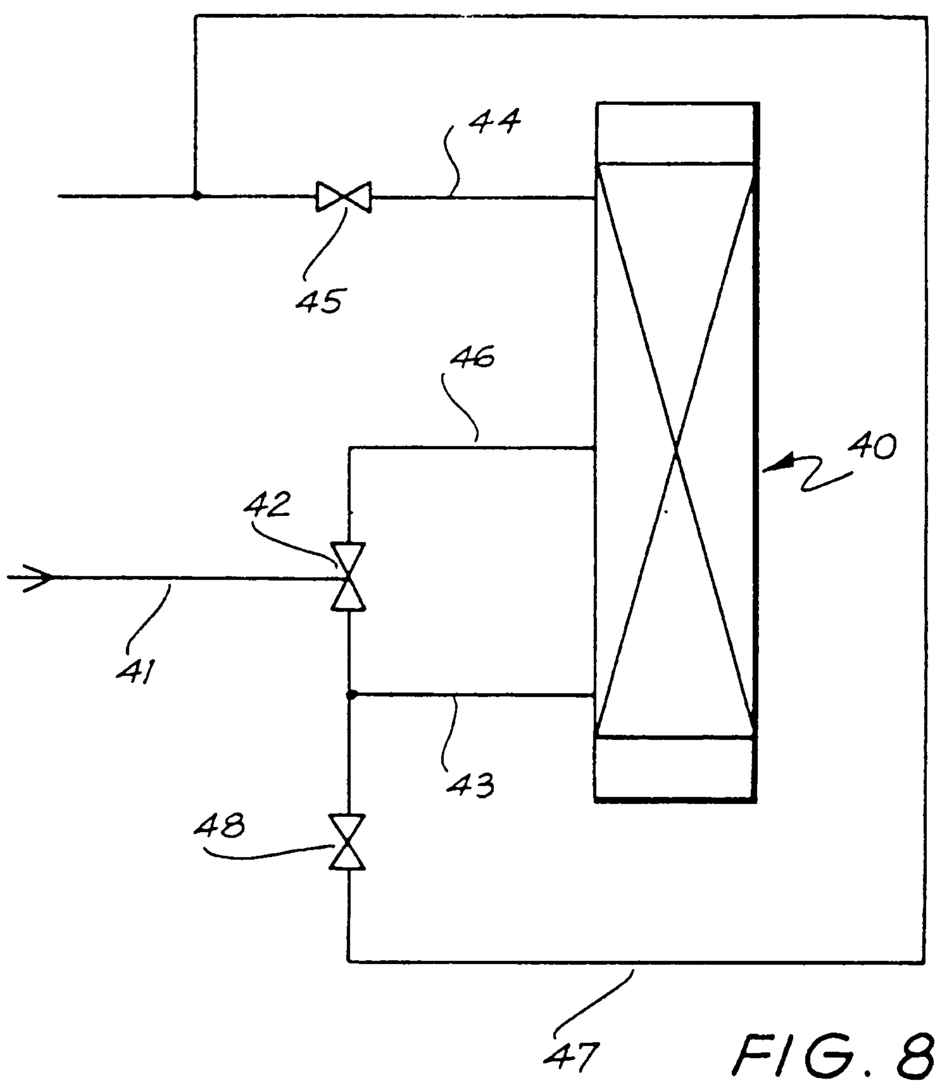

FIG. 8

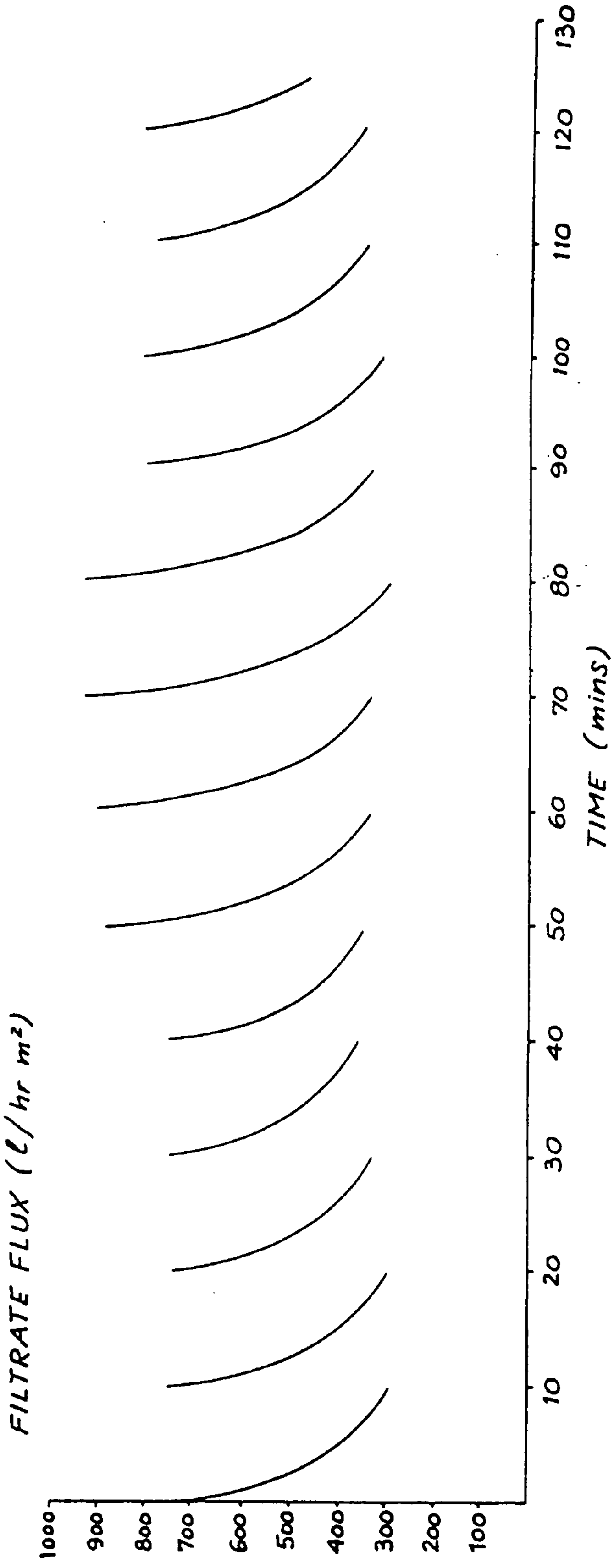
FILTRATE FLUX (ℓ/hr m²)
1000
900
800
700
600
500
400
300
200
100
10
20
30
40
50
60
70
80
90
100
110
120
130
TIME (mins)

FIG. 9

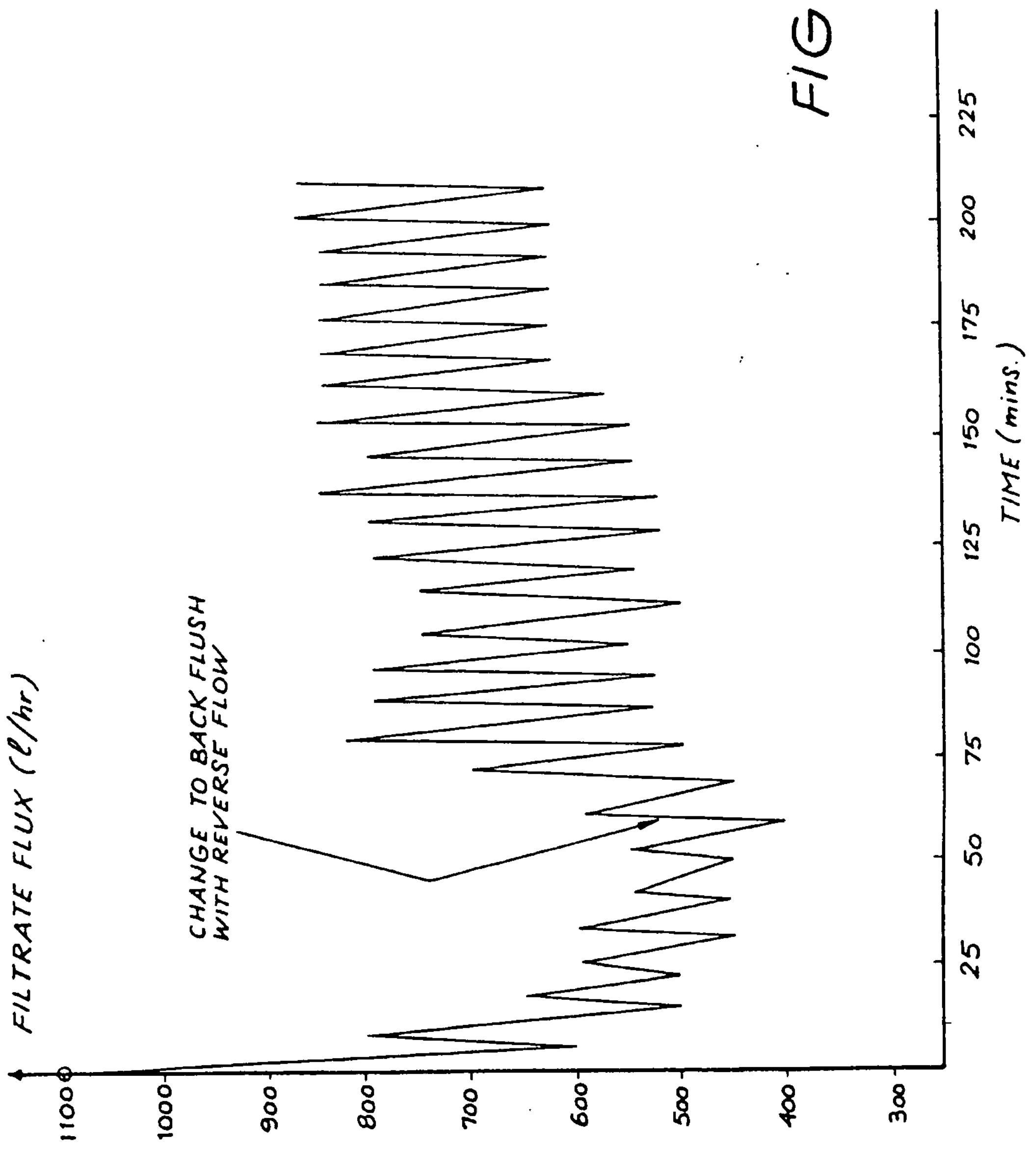
FILTRATE FLUX (ℓ/hr)
1100
1000
900
800
700
600
500
400
300
CHANGE TO BACK FLUSH WITH REVERSE FLOW
25
50
75
100
125
150
175
200
225
TIME (mins.)

FIG. 10

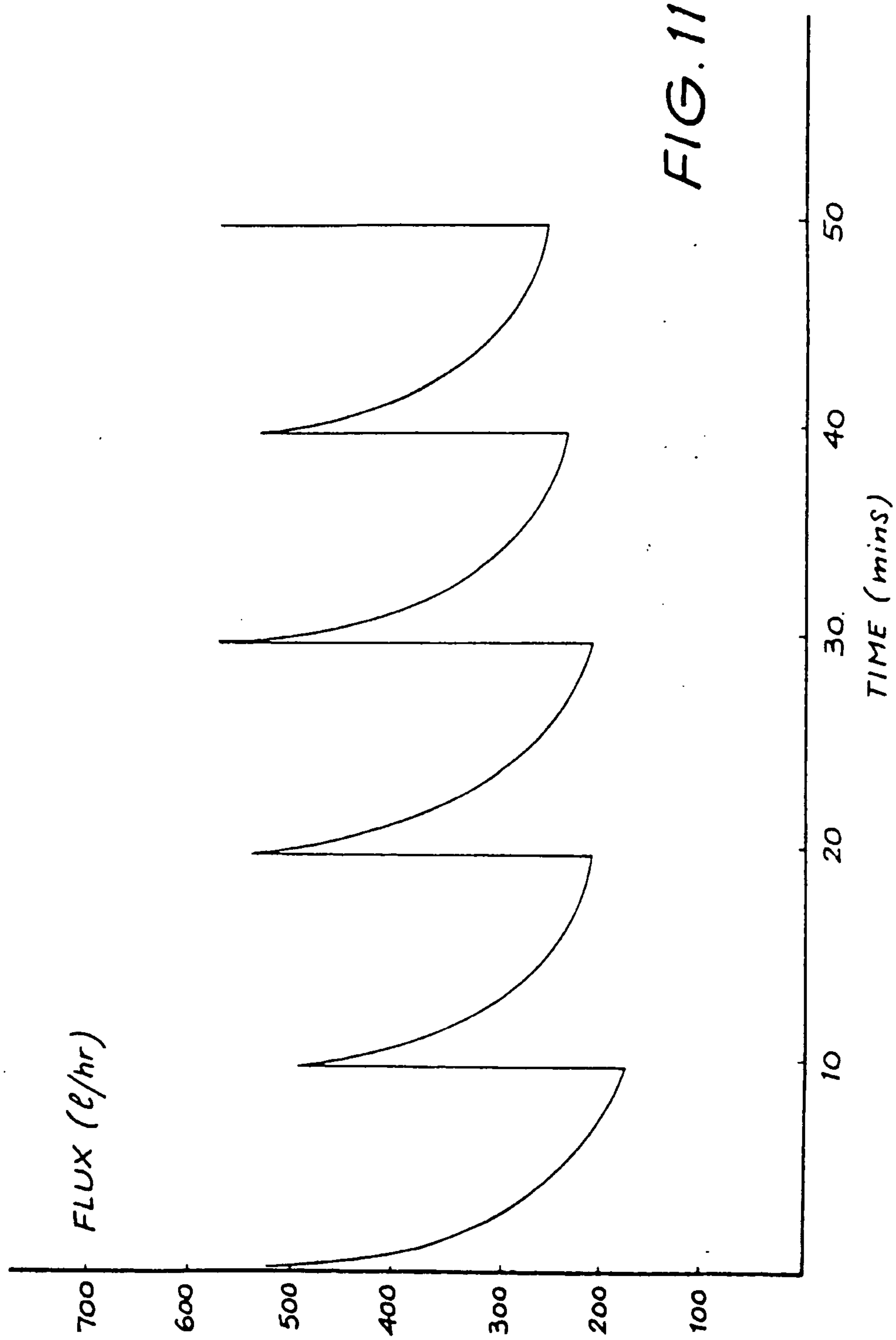

FIG. 11

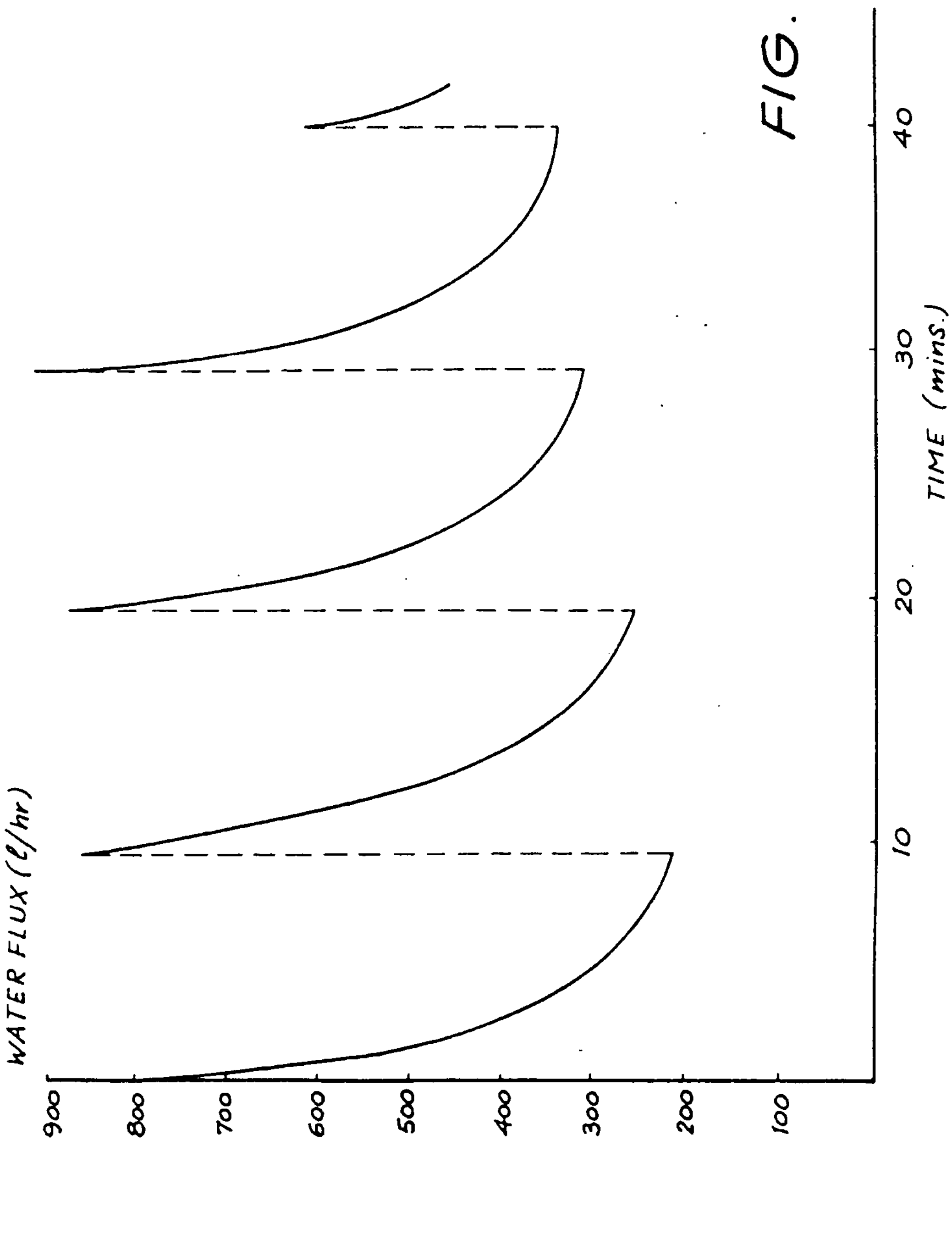
WATER FLUX (ℓ/hr)
900
800
700
600
500
400
300
200
100
10
20
30
40
TIME (mins.)

FIG. 12

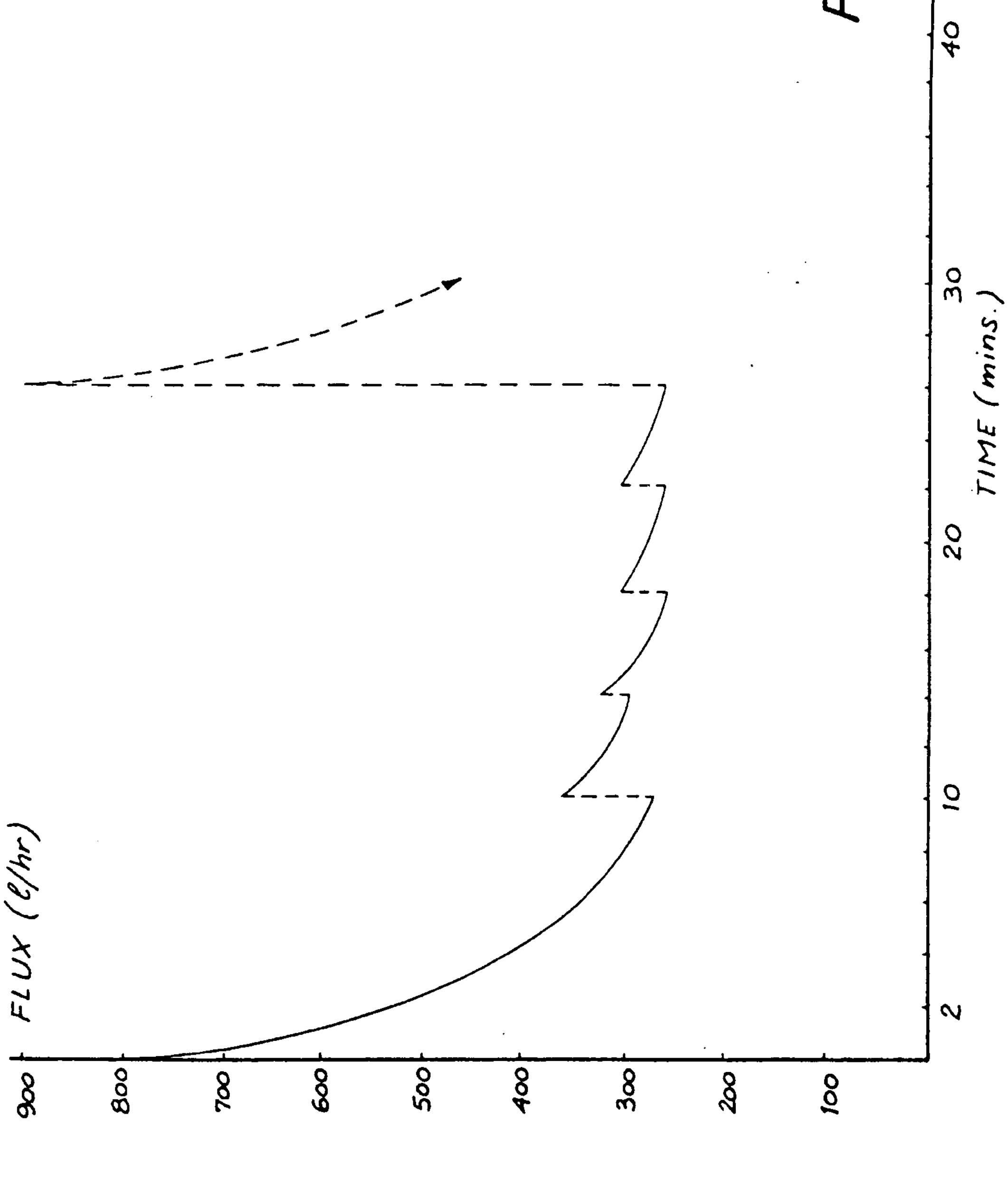
FLUX (ℓ/hr)
900
800
700
600
500
400
300
200
100
2
10
20
30
40
TIME (mins.)

FIG. 13